CHEM110 – Chapter 6
Gases

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6.7 Real Gases

- Melting and boiling points
  - Can be used as indicators of the strengths of intermolecular forces
  - The boiling point is the temperature at which the average kinetic energy of molecular motion balances the attractive energy of intermolecular attractions
  - When the pressure is 1.013×10^5 Pa, that temperature is the normal boiling point

6.7 Real Gases

- Melting and boiling points
  - The conversion of a liquid into a gas is called vaporisation
  - Condensation is the reverse process
  - At temperatures below the freezing point, the molecules become locked in place and the liquid solidifies. When the pressure is 1.013×10^5 Pa, that temperature is the normal freezing point
  - Boiling and melting points depend on the strengths of intermolecular forces

6.8 Intermolecular Forces

There are three general types:

- Dispersion forces
  - The attractions between the negatively charged electron clouds & the positively charged nuclei of neighbouring molecules. All substances display dispersion forces

6.8 Intermolecular Forces

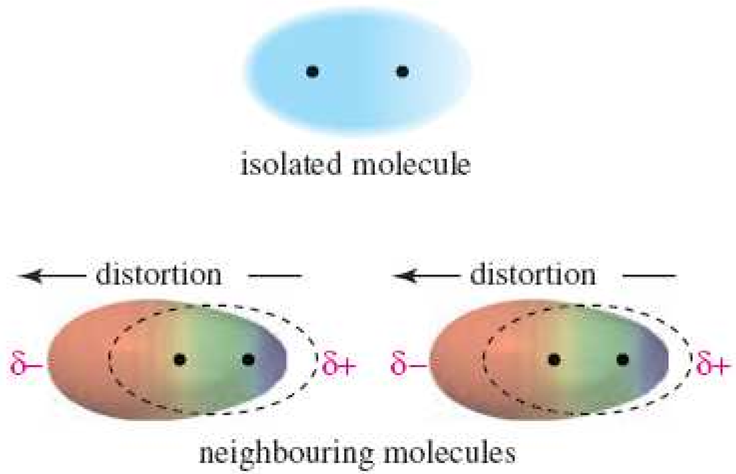
There are three general types:

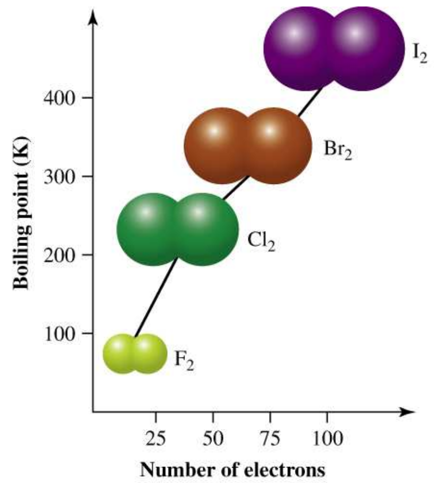
- Dipole-induced dipole forces
  - A molecule with a permanent dipole induces a dipole in a neighbouring molecule

- Dipole-dipole forces
  - Attractions between negatively charged end of a polar molecule & positively charged end of another molecule (special case: hydrogen bond)

6.8 Intermolecular Forces

- Dispersion forces
  - Exists because the electron clouds of molecules can be distorted





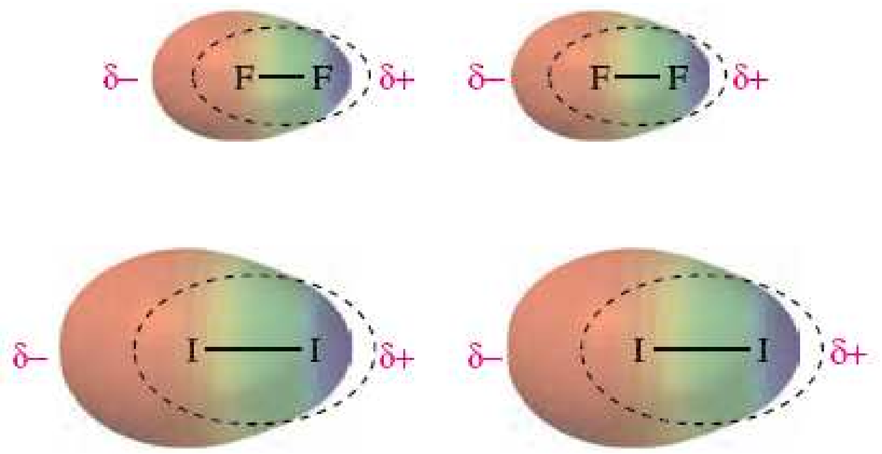
  - Dispersion forces are the net attractive forces between molecules generated by all these induced charge imbalances

6.8 Intermolecular Forces

Dispersion forces

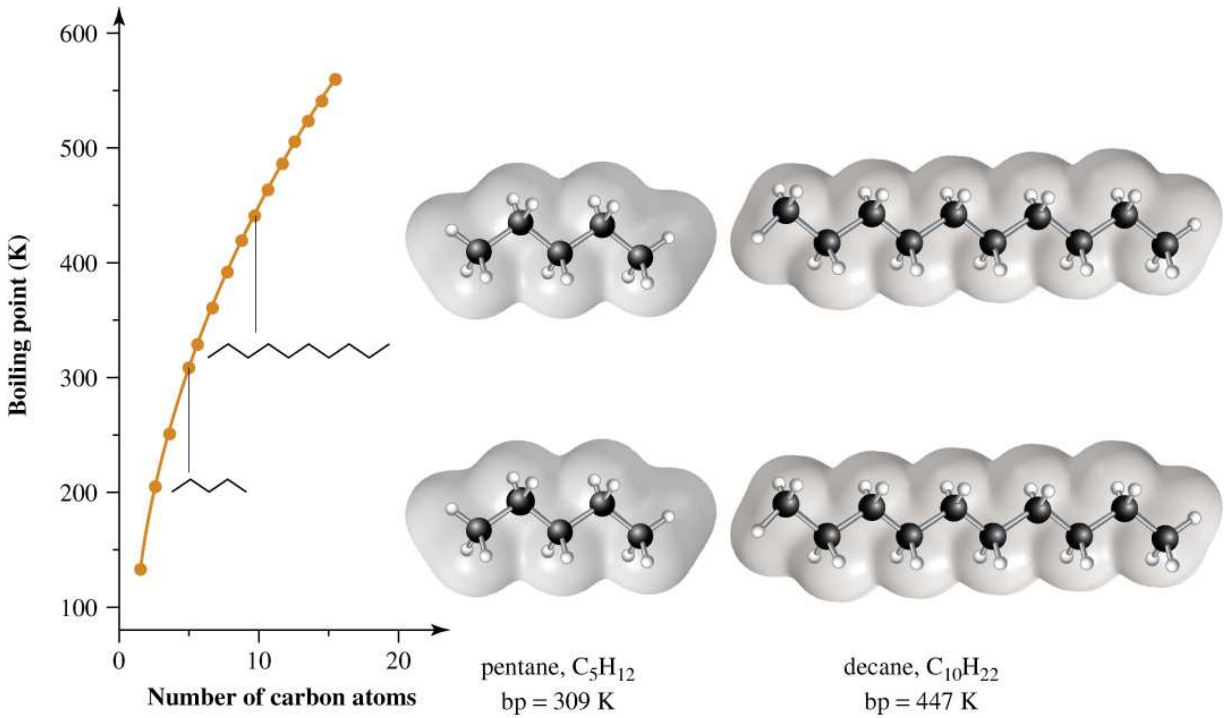
- The magnitude of dispersion forces depends on how easy it is to distort the electron cloud of a molecule

- This ease of distortion is called the **polarisability** and increases with increased size of the electron cloud



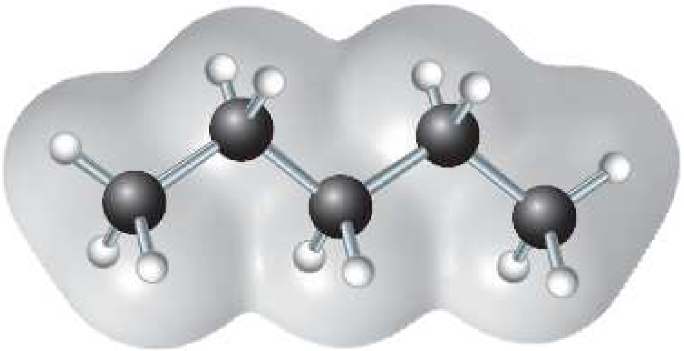
6.8 Intermolecular Forces

- Dispersion forces increase in strength with increasing numbers of electrons as larger electron clouds are more polarisable than smaller ones

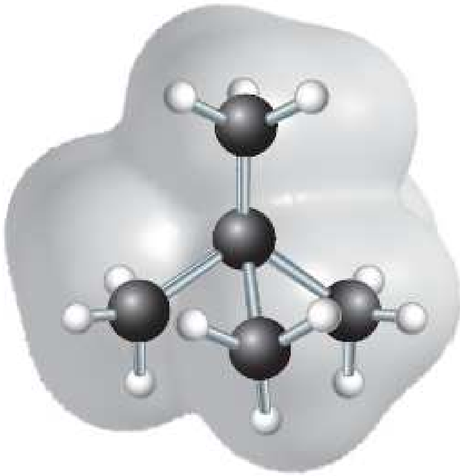


6.8 Intermolecular Forces

- For molecules with comparable numbers of electrons, the shape of the molecule makes an important secondary contribution to the magnitude of dispersion forces
- More compact $\rightarrow$ less polarisable



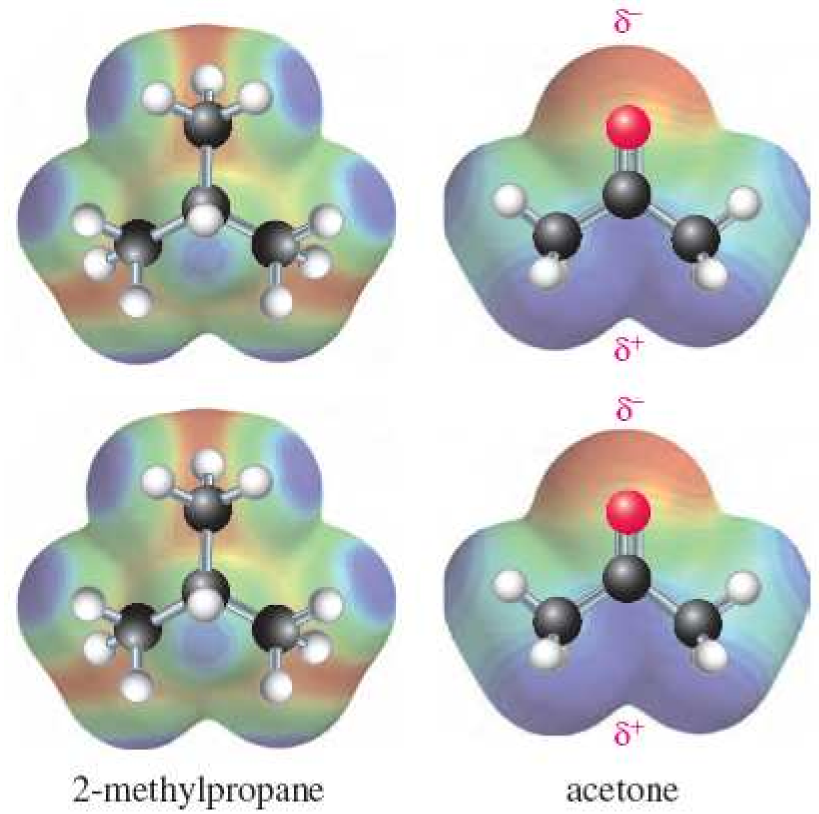
pentane, C_5H_{12}
bp = 309 K



2,2-dimethylpropane, C_5H_{12}
bp = 283 K

6.8 Intermolecular Forces

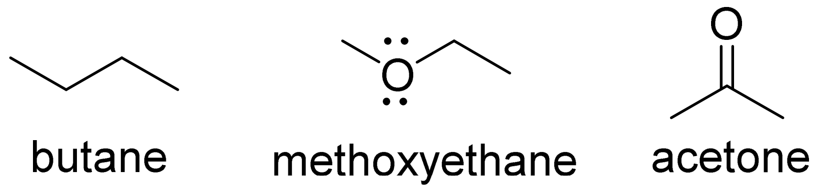
- Dipolar forces
  - Molecules with a large dipole moment display dipolar forces
  - The C=O bond is highly polarised and therefore acetone has a large dipolar moment



6.8 Intermolecular Forces

– Worked Example 6.13 (page 243)

The line structures of butane, methoxyethane and acetone are shown below. Explain the trend in boiling points: butane (273K), methoxyethane (281K), and acetone (329K)



6.8 Intermolecular Forces

Hydrogen bonds

- Two requirements:
  - First, there must be an electron-deficient hydrogen atom that can be attracted to an electron pair

    (Hydrogen atoms in O-H, F-H and N-H bonds)

  - Second, there must be a small, highly electronegative atom with an electron pair that can interact with the electron-deficient hydrogen atom

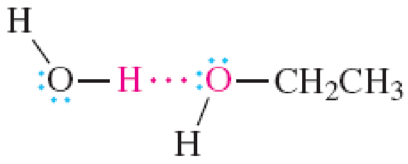
- Can form between different molecules and also within a molecule

- Molecules can form more than one

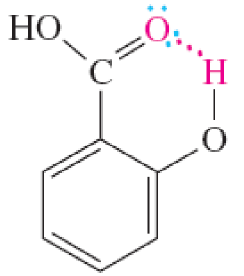
6.8 Intermolecular Forces

- Hydrogen bonds
  - Examples:

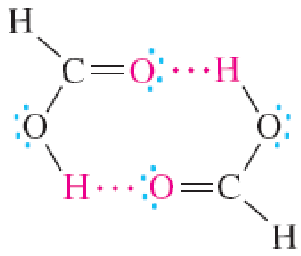
hydrogen fluoride



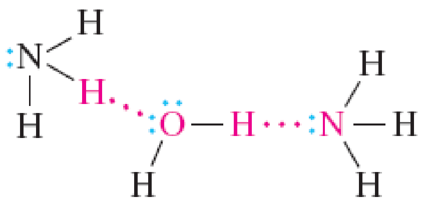
water–ethanol



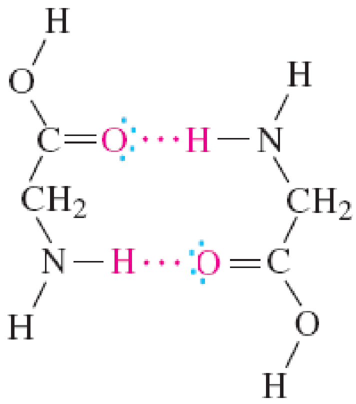
salicylic acid



formic acid



ammonia–water



glycine
(an amino acid)

6.8 Intermolecular Forces

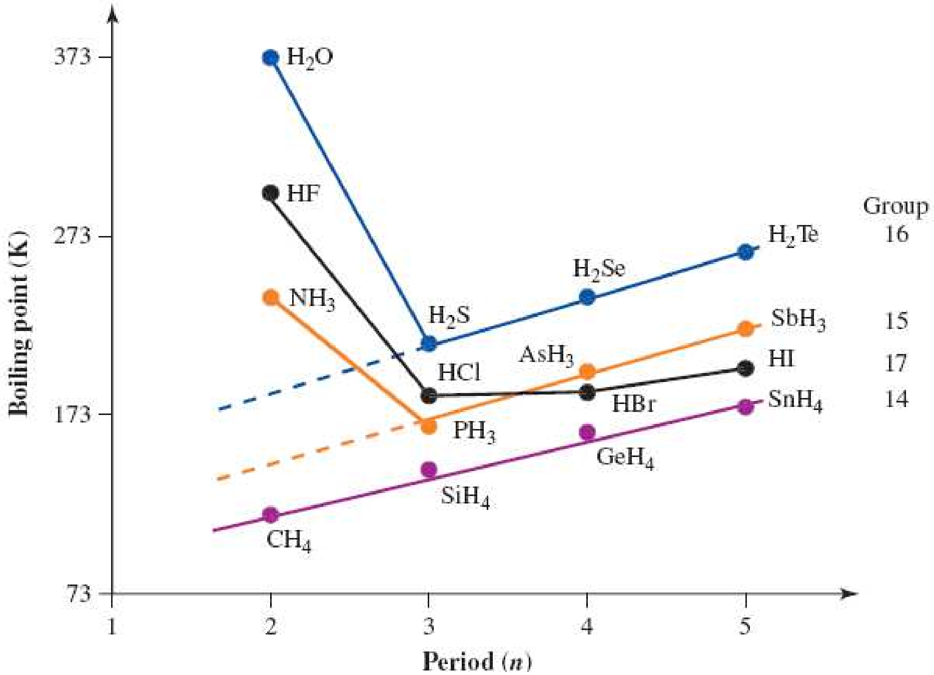
University of New England

Worked example 6.14

In which of the following systems will hydrogen bonding play an important role: CH_3F, $(CH_3)_2CO$ (acetone), CH_3OH, and NH_3 dissolved in $(CH_3)_2CO$ (acetone)?

6.8 Intermolecular Forces

- Binary hydrogen compounds
  - It is both the strength and number of hydrogen bonds that a binary hydrogen compound can form which determines its boiling point



Chapter Summary

- The three common states of matter are solid, liquid and gas
- Gases occupy all of the space in which they are contained
- The pressure exerted by a gas is due to the collisions of rapidly moving gas atoms or molecules with the walls of the container

Chapter Summary

Gas relationships -

- Boyle's Law (volume and pressure)
- Charles' Law (volume and temperature)
- Avogadro's Law (volume and amount of a gas)

- The combination of these laws gives the ideal gas equation:

$$pV = nRT$$

Chapter Summary

- In order to determine the kinetic energy of a gas molecule, it is necessary to measure the speed with which it is moving
- All gases have an identical molecular kinetic energy distribution at a given temperature
- The movement of gas molecules can be described as either effusion or diffusion
- Each gaseous component in a mixture of ideal gases exerts a partial pressure

Chapter Summary

- The mole fraction of a substance equals the ratio of moles to the total number of moles
- The ideal gas equation can be used to determine molar mass and gas density
- Real gases approximate ideal behaviour under certain conditions
- Intermolecular forces are partially responsible for the fact that real gases do not exactly obey the ideal gas laws
- The van der Waals equation for a real gas makes corrections for the volume of the gas molecules and for the attractive force between them

Chapter Summary

- Melting and boiling points give good indications of the strength of intermolecular forces

- There are three general types of intermolecular forces:
  - Dispersion forces (exists in all molecules)
  - Dipole-induced dipole forces
  - Dipole-dipole forces (including hydrogen bonds)
  - Dipolar forces exists in molecules with a large dipolar moment