CHEM1101 Worksheet 7: Intermolecular Forces

Information

Intermolecular forces are the interactions *between* rather than *inside* molecules. They are responsible for many of the physical properties of substances, including their melting and boiling points.

In pure substances, there are 3 important intermolecular forces which may be present:

- *Dipole – dipole forces*. The dipole moment in a molecule will tend to align with those in its neighbours. This type of interaction is only possible if the molecule possesses a dipole.
- *Hydrogen bonds*. This is a particularly strong dipole – dipole interaction involving the interaction between the δ+ H atoms in very polar bonds and lone pairs on very electronegative atoms. Hydrogen bonding therefore requires the presence of both δ+ H atoms *and* electronegative atoms.
- *Dispersion forces*. These forces are present in *all* molecules and atoms. At any moment in time, the electron density in a molecule or atom may not be symmetrical and this leads to a dipole moment. This momentary or *instantaneous* dipole moment *induces* a matching dipoles in neighbouring molecules or atoms by polarizing their electron density.

  Dispersion forces increase with the number of electrons in a molecule.

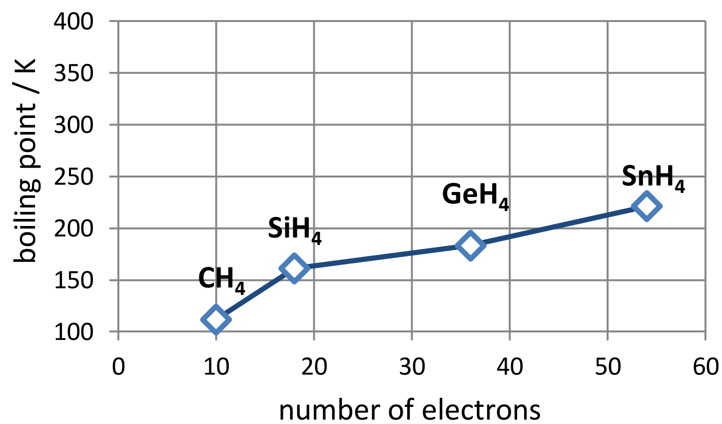
Model 1: Boiling Points Change Down a Group of the Periodic Table

Molecules are held in the liquid phase due to intermolecular forces so that boiling points are a good guide to their strength.

The figure opposite shows the boiling points of the Group 14 hydrides. All have the same shape but differ in the total number of electrons.

For example:

- C has 6 electrons and each H has 1 electron so CH_4 has $6 + 4 \times 1 = 10$.
- Sn has 50 electrons so SnH_4 has 54 electrons.



Critical thinking questions

1. What happens to the boiling point as the number of electrons increases?

2. What shape are the Group 14 hydrides?

3. Are dipole – dipole forces present in these molecules?

4. Is hydrogen bonding possible in these molecules?

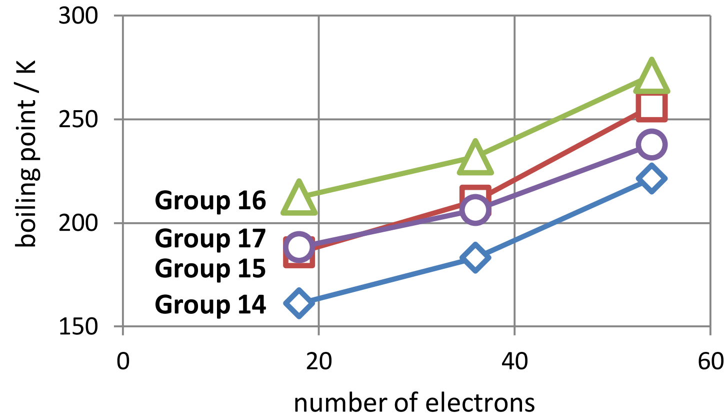
5. What intermolecular force is present in these molecules?

6. Explain why the boiling points vary in the way you described in answer to Q1.

Model 2: Boiling Points Change Across a Row of the Periodic Table

On the graph opposite, the boiling points for the other hydrides have been added:

- Group 14 SiH_4, GeH_4 and SnH_4
- Group 15 PH_3, AsH_3 and SbH_3
- Group 16 H_2S, H_2Se and H_2Te
- Group 17 HCl, HBr and HI



Critical thinking questions

1. Use a Periodic Table to confirm that SiH_4, PH_3, H_2S and HCl all have 18 electrons.

2. What happens to the boiling point as the number of electrons increases? Why?

3. What is the molecular shape of PH_3, H_2S and HCl?

4. Do PH_3, H_2S and HCl have dipole moments?

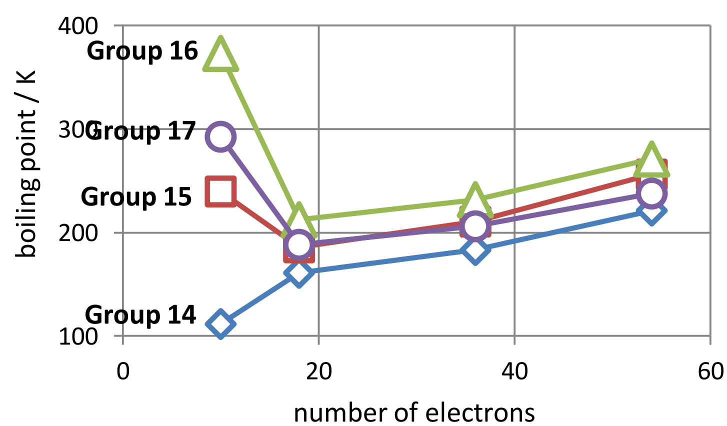
5. Why is the boiling point of SiH_4 *lower* than that of PH_3, H_2S and HCl?

6. Is the boiling point of SnH_4 (54 electrons) higher or lower than the boiling point of PH_3 (18 electrons)?

7. Explain your answer to Q6, making sure that it is consistent with your answers to Q2 and Q5.

Model 3: Anomalous Boiling Points of NH_3, H_2O and HF

The graph opposite adds the boiling points of CH_4, NH_3, H_2O and HF to Model 3. N, O and F are very electronegative and N-H, O-H and H-F bonds are very polar.



Critical thinking questions

1. How do the boiling points of the Group 14 hydrides change down the group?

Re-read your answers to Model 1.

2. How many δ+ H atoms are there on the most electronegative element in the molecules below?

(a) NH_3 (b) H_2O (c) HF

3. How many lone pairs are there on the most electronegative element in these molecules?

(a) NH_3 (b) H_2O (c) HF

4. Explain why the boiling points of NH_3, H_2O and HF (10 electrons) are *higher* than those of PH_3, H_2S and HCl (18 electrons) Refer to the **Information** if you are unsure.

5. Given your answer to Q4, suggest why the boiling point of NH_3 (10 electrons) is *lower* than that of SbH_3 (54 electrons).

6. Order the N-H, O-H and F-H bonds in terms of their polarity.

7. Predict the *relative* strength of the intermolecular forces between *two* NH_3 molecules, *two* H_2O and *two* HF molecules.

8. How many hydrogen bonds can each NH_3 molecule make on average in NH_3(l)? (*Hint*: re-read your answers to Q2 and Q3).

9. How many hydrogen bonds can each HF molecule make on average in HF(l)? (*Hint*: re-read your answers to Q2 and Q3).

10. How many hydrogen bonds can each H_2O molecule make on average in H_2O(l)? (*Hint*: re-read your answers to Q2 and Q3).

11. Use your answers to Q6 – Q10 to explain why the boiling points vary in the order $NH_3 < HF < H_2O$.

12. Many textbooks and websites state that dispersion forces are *weaker* than hydrogen bonding and dipole – dipole forces. *Critically* analyse this statement in the light of the evidence in Models 1 – 3.

Research Project on Global Warming Assignment - deadline is the end of week 11

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Marks 4

- Explain the trend in the following table in terms of the type and size of intermolecular forces.

Substance	Boiling point (°C)
CH_3CH_3	–89
$CH_3CH_2CH_2CH_3$	–1
CH_3CH_2–O–CH_2CH_3	35
CH_3CH_2OH	78
H_2O	100

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Marks 2

- Circle the molecule in the following pairs that has the stronger intermolecular forces. Identify the types of forces present for the species selected.

molecule pair	types of intermolecular forces
H_2 or N_2	
CH_3Cl or CH_4	
SO_2 or CO_2	
H_2O or H_2S	