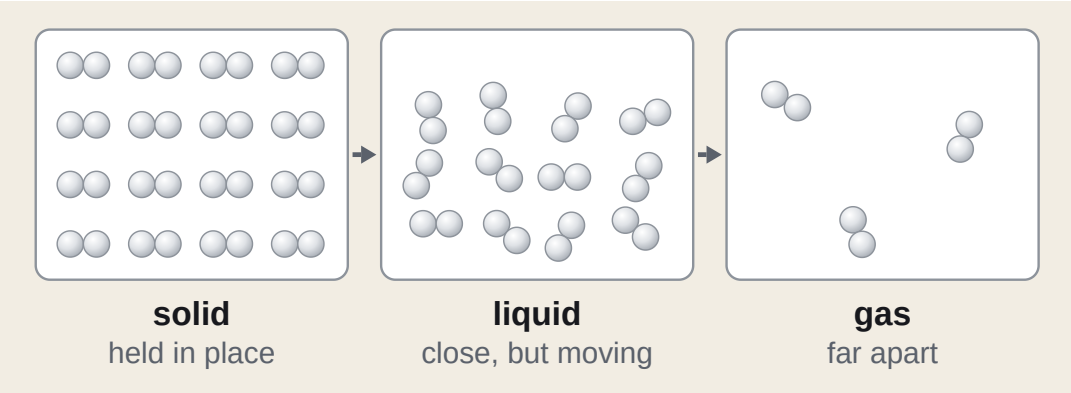
A12 · Predicting boiling points and solubility · Completed notes

Goals: Explain why stronger intermolecular forces give higher melting and boiling points. Compare the boiling points of two molecular substances from their forces and their electrons. Predict whether two liquids mix, and compare ionic and molecular substances.

These are the completed notes. The blanks are filled in and each question is worked.

Slide 1 of 7 · Stronger forces, higher melting and boiling points

In lesson A11 you listed the forces between molecules. Today those forces explain something you can see. Why is one substance a gas and another a solid in the same room?



Key ideas

To boil a liquid, its molecules must be pulled **far apart**.

This needs **energy** to overcome intermolecular forces.

No **covalent bond** breaks.

Stronger forces give **higher** melting and boiling points.

Example

Substance X has stronger intermolecular forces than substance Y. Which has the higher boiling point? Say why.

1. Stronger forces need more energy to overcome.
2. So substance X has the higher boiling point.

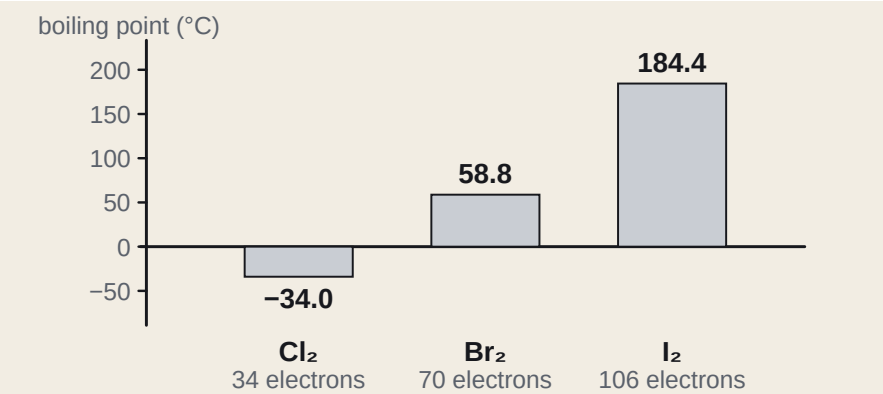
Try it

When water boils, do the bonds inside the H_2O molecules break? Say what happens.

1. No. No covalent bond breaks.
2. The molecules are pulled far apart.
3. Only intermolecular forces are overcome.

Slide 2 of 7 · Same kinds of force: count the electrons

On the last slide, stronger forces gave a higher boiling point. Now test that with real values. Start with a family where only one thing changes.



Key ideas

Cl_2, Br_2 and I_2 each have **London forces** only.

I_2 has **106** electrons, the most of the three.

More electrons give **stronger** London forces.

So I_2 boils at the highest temperature, **184.4** °C.

Example

Neon has 10 electrons and argon has 18. Both have London forces only. Which has the higher boiling point? Say why.

1. Argon has more electrons, so its London forces are stronger.
2. So argon has the higher boiling point.

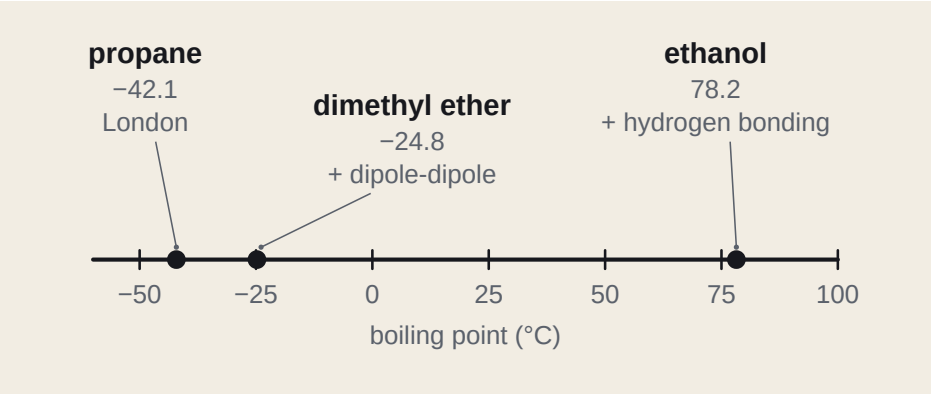
Try it

Methane, CH_4, has 10 electrons. Propane, C_3H_8, has 26. Both are non-polar. Which has the higher boiling point? Say why.

1. Both have London forces only.
2. Propane has more electrons, so its London forces are stronger.
3. So propane has the higher boiling point.

Slide 3 of 7 · Same number of electrons: compare the kinds of force

On the last slide, the kind of force stayed the same and the electrons changed. Now hold the electrons steady and change the kinds of force.



Key ideas

Propane, dimethyl ether and ethanol each have **26** electrons.

Their London forces are about **equal**.

Dimethyl ether is polar, so it adds **dipole-dipole forces**.

Ethanol adds **hydrogen bonding**, so it boils highest.

Example

F_2 and HCl each have 18 electrons. F_2 is non-polar and HCl is polar. Which has the higher boiling point? Say why.

1. Their London forces are about equal.
2. HCl adds dipole-dipole forces.
3. So HCl has the higher boiling point.

Try it

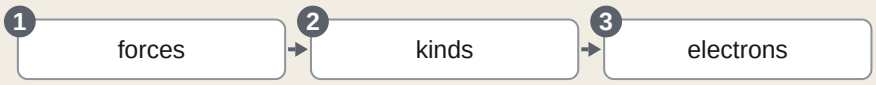
Ethane, C_2H_6, and methanol, CH_3OH, each have 18 electrons. Methanol has a hydrogen bonded to oxygen. Which has the higher boiling point? Say why.

1. Their London forces are about equal.
2. Methanol adds dipole-dipole forces and hydrogen bonding.
3. So methanol has the higher boiling point.

Slide 4 of 7 · Method: how to compare two boiling points

You just compared two sets of boiling points. Each time you looked at the electrons and the kinds of force. Here that is as three steps.

1. **List** the forces of each substance.
2. **Compare** the kinds of force.
3. **Count** electrons if the kinds are the same.



Check: stronger forces give a higher boiling point.

Used again in: the unit review

Key ideas

Step 1: list the **forces** of each substance.

Step 2: compare the **kinds** of force.

Step 3: if the kinds are the same, compare the **electrons**.

Example

Use the three steps to compare the boiling points of ethane, C_2H_6, and propane, C_3H_8.

1. Step 1: both are non-polar, so each has London forces only.
2. Step 2: the kinds of force are the same.
3. Step 3: ethane has 18 electrons and propane has 26.
4. So propane has the higher boiling point.

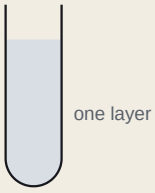
Try it

Use the three steps to compare the boiling points of water, H_2O, and methane, CH_4.

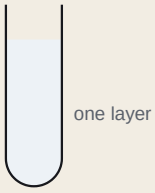
1. Step 1: methane has London forces only. Water has all three kinds.
2. Step 2: water has more kinds of force.
3. Step 3: both have 10 electrons, so their London forces are about equal.
4. So water has the higher boiling point.

Slide 5 of 7 · Will two liquids mix?

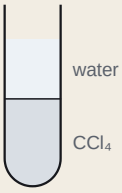
So far the forces acted between molecules of one substance. The same forces act between two different liquids. They decide whether the liquids mix.



Br_2 and CCl_4
Both are non-polar, so they mix.



H_2O_2 and water
Both hydrogen bond, so they mix.



CCl_4 and water
Their forces are not alike, so two layers form.

Key ideas

Two liquids mix when their intermolecular forces are **alike**.

Bromine and carbon tetrachloride are both **non-polar**, so they mix.

Hydrogen peroxide and water both have **hydrogen bonding**, so they mix.

Water and carbon tetrachloride stay apart, in **two layers**.

Example

Will ethanol and water mix? Say why.

1. Both have hydrogen bonding.
2. Their forces are alike, so they mix.

Try it

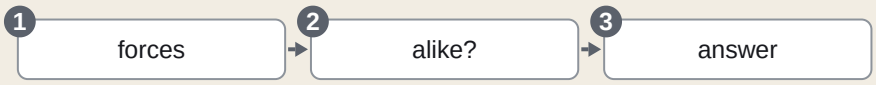
Hexane, C_6H_{14}, is non-polar. Will hexane and water mix? Say why.

1. Hexane has London forces only. Water has hydrogen bonding.
2. Their forces are not alike, so they do not mix.
3. They stay apart, in two layers.

Slide 6 of 7 · Method: how to predict whether two liquids mix

You just judged three pairs of liquids. Each time you compared their forces. Here that is as three steps.

1. **List** the forces of each liquid.
2. **Compare** the kinds of force. Are they alike?
3. **Predict** mixing if alike, two layers if not.



Check: like mixes with like.

Used again in: Unit C, solutions

Key ideas

Step 1: list the **forces** of each liquid.

Step 2: ask if the forces are **alike**.

Step 3: write the **answer**: they mix, or they do not mix.

Example

Use the three steps on bromine, Br_2, and hexane, C_6H_{14}. Both are non-polar.

1. Step 1: each has London forces only.
2. Step 2: the forces are alike.
3. Step 3: the two liquids mix.

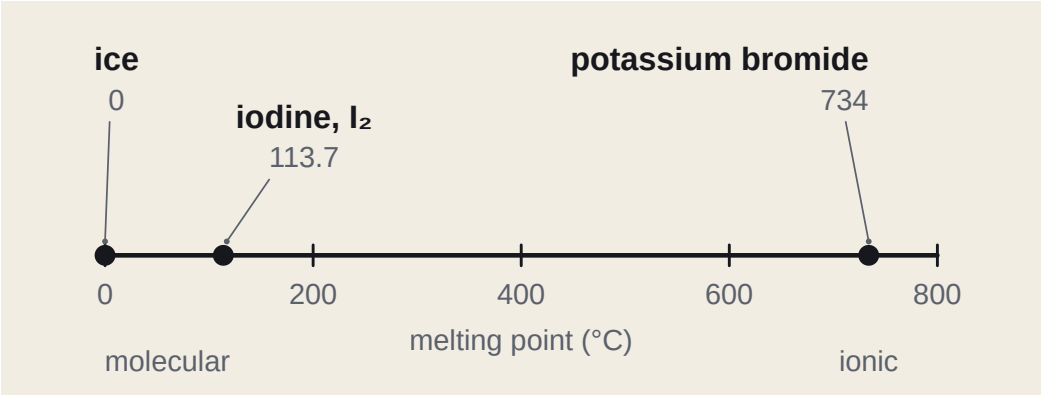
Try it

Use the three steps on methanol, CH_3OH, and water. Methanol has a hydrogen bonded to oxygen.

1. Step 1: both have hydrogen bonding.
2. Step 2: the forces are alike.
3. Step 3: the two liquids mix.

Slide 7 of 7 · Ionic or molecular?

Lessons A3 and A4 were about ionic compounds. Lessons A5 to A12 were about molecules. Put the two halves of this unit side by side.



Key ideas

Melting an ionic solid pulls **ions** apart.

Ionic bonds are **strong**.

Melting a molecular solid overcomes only **intermolecular forces**.

So ionic compounds melt far **higher** than molecular substances.

Example

Sodium chloride is ionic. Sugar is molecular. Which melts at the higher temperature? Say why.

1. Melting sodium chloride pulls ions apart. Ionic bonds are strong.
2. Melting sugar overcomes only intermolecular forces.
3. So sodium chloride melts at the higher temperature.

Try it

Calcium oxide is ionic. Ice is molecular. Which melts at the higher temperature? Say why.

1. Melting calcium oxide pulls ions apart. Ionic bonds are strong.
2. Melting ice overcomes only intermolecular forces.
3. So calcium oxide melts at the higher temperature.