Kinetic molecular theory: Properties of matter*

Free High School Science Texts Project

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1 The Properties of Matter

Let us now look at what we have learned about chemical bonds, intermolecular forces and the kinetic theory of matter, and see whether this can help us to understand some of the macroscopic properties of materials.

1. **Melting point**

   Definition 1: Melting point
   The temperature at which a *solid* changes its phase or state to become a *liquid*. The process is called melting and the reverse process (change in phase from liquid to solid) is called **freezing**.

   In order for a solid to melt, the energy of the particles must increase enough to overcome the bonds that are holding the particles together. It makes sense then that a solid which is held together by strong bonds will have a *higher* melting point than one where the bonds are weak, because more energy (heat) is needed to break the bonds. In the examples we have looked at metals, ionic solids and some atomic lattices (e.g. diamond) have high melting points, whereas the melting points for molecular solids and other atomic lattices (e.g. graphite) are much lower. Generally, the intermolecular forces between molecular solids are *weaker* than those between ionic and metallic solids.
2. **Boiling point**

   Definition 2: Boiling point
   The temperature at which a *liquid* changes its phase to become a *gas*. The process is called evaporation and the reverse process is called condensation

   When the temperature of a liquid increases, the average kinetic energy of the particles also increases and they are able to overcome the bonding forces that are holding them in the liquid. When boiling point is reached, *evaporation* takes place and some particles in the liquid become a gas. In other words, the energy of the particles is too great for them to be held in a liquid anymore. The stronger the bonds within a liquid, the higher the boiling point needs to be in order to break these bonds. Metallic and ionic compounds have high boiling points while the boiling point for molecular liquids is lower. The data in Table 1 below may help you to understand some of the concepts we have explained. Not all of the substances in the table are solids at room temperature, so for now, let's just focus on the *boiling points* for each of these substances. What do you notice?

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Substance	**Melting point ($^{\circ}C$)**	**Boiling point ($^{\circ}C$)**
Ethanol (C_2H_6O)	- 114,3	78,4
Water	0	100
Mercury	-38,83	356,73
Sodium chloride	801	1465

Table 1: The melting and boiling points for a number of substances

You will have seen that substances such as ethanol, with relatively weak intermolecular forces, have the lowest boiling point, while substances with stronger intermolecular forces such as sodium chloride and mercury, must be heated much more if the particles are to have enough energy to overcome the forces that are holding them together in the liquid. See the section (Section 1.1: Exercise: Forces and boiling point) below for a further exercise on boiling point.

3. **Density and viscosity**

   NOTE: Density and viscosity is not in CAPS - Included for Completeness

   Definition 3: Density
   Density is a measure of the mass of a substance per unit volume.

   The density of a solid is generally higher than that of a liquid because the particles are held much more closely together and therefore there are more particles packed together in a particular volume. In other words, there is a greater mass of the substance in a particular volume. In general, density increases as the strength of the intermolecular forces increases.

   Definition 4: Viscosity
   Viscosity is a measure of how resistant a liquid is to flowing (in other words, how easy it is to pour the liquid from one container to another).

   Viscosity is also sometimes described as the 'thickness' of a fluid. Think for example of syrup and how slowly it pours from one container into another. Now compare this to how easy it is to pour water. The viscosity of syrup is greater than the viscosity of water. Once again, the stronger the intermolecular forces in the liquid, the greater its viscosity.

It should be clear now that we can explain a lot of the **macroscopic properties** of matter (i.e. the characteristics we can see or observe) by understanding their **microscopic structure** and the way in which the atoms and molecules that make up matter are held together.

1.1 Exercise: Forces and boiling point

The table below gives the molecular formula and the boiling point for a number of organic compounds called *alkanes* (more on these compounds in grade 12). Refer to the table and then answer the questions that follow.

Organic compound	Molecular formula	Boiling point ($^{\circ}C$)
Methane	CH_4	-161.6
Ethane	C_2H_6	- 88.6
Propane	C_3H_8	-45
Butane	C_4H_{10}	-0.5
Pentane	C_5H_{12}	36.1
Hexane	C_6H_{14}	69
Heptane	C_7H_{16}	98.42
Octane	C_8H_{18}	125.52

Table 2

Data from: http://www.wikipedia.com

1. Draw a graph to show the relationship between the number of carbon atoms in each alkane and its boiling point. (Number of carbon atoms will go on the x-axis and boiling point on the y-axis).
2. Describe what you see.
3. Suggest a reason for what you have observed.
4. Why was it enough for us to use 'number of carbon atoms' as a measure of the molecular weight of the molecules?

Click here for the solution[1]

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Figure 1

[1] http://www.fhsst.org/liP