The kinetic molecular theory*

Free High School Science Texts Project

This work is produced by The Connexions Project and licensed under the
Creative Commons Attribution License †

1 The Kinetic Theory of Matter

The **kinetic theory of matter** helps us to explain why matter exists in different *phases* (i.e. solid, liquid and gas), and how matter can change from one phase to the next. The kinetic theory of matter also helps us to understand other properties of matter. It is important to realise that what we will go on to describe is only a *theory*. It cannot be proved beyond doubt, but the fact that it helps us to explain our observations of changes in phase, and other properties of matter, suggests that it probably is more than just a theory.

Broadly, the Kinetic Theory of Matter says that:

- Matter is made up of **particles** that are constantly moving.
- All particles have **energy**, but the energy varies depending on whether the substance is a solid, liquid or gas. Solid particles have the least amount of energy and gas particles have the greatest amount of energy.
- The **temperature** of a substance is a measure of the *average kinetic energy* of the particles.
- A change in **phase** may occur when the energy of the particles is changed.
- There are **spaces** between the particles of matter.
- There are **attractive forces** between particles and these become stronger as the particles move closer together. These attractive forces will either be intramolecular forces (if the particles are atoms) or intermolecular forces (if the particles are molecules). When the particles are extremely close, repulsive forces start to act.

Table 1 summarises the characteristics of the particles that are in each phase of matter.

Property of matter	**Solid**	**Liquid**	**Gas**
Particles	Atoms or molecules	Atoms or molecules	Atoms or molecules
Energy and movement of particles	Low energy - particles vibrate around a fixed point	Particles have less energy than in the gas phase	Particles have high energy and are constantly moving
			continued on next page

*Version 1.2: Sep 29, 2011 5:26 am -0500
†http://creativecommons.org/licenses/by/3.0/

Spaces between particles	Very little space between particles. Particles are tightly packed together	Smaller spaces than in gases, but larger spaces than in solids	Large spaces because of high energy
Attractive forces between particles	Very strong forces. Solids have a fixed volume.	Stronger forces than in gas. Liquids can be poured.	Weak forces because of the large distance between particles
Changes in phase	Solids become liquids if their temperature is increased. In some cases a solid may become a gas if the temperature is increased.	A liquid becomes a gas if its temperature is increased. It becomes a solid if its temperature decreases.	In general a gas becomes a liquid when it is cooled. (In a few cases a gas becomes a solid when cooled). Particles have less energy and therefore move closer together so that the attractive forces become stronger, and the gas becomes a liquid (or a solid.)

Table 1: Table summarising the general features of solids, liquids and gases.

The following presentation is a brief summary of the above. Try to fill in the blank spaces before clicking onto the next slide.

This media object is a Flash object. Please view or download it at
<http://static.slidesharecdn.com/swf/ssplayer2.swf?doc=kinetictheory-done-100510040904-phpapp02&stripped_title=kinetic-theory-done>

Figure 1

Let's look at an example that involves the three phases of water: ice (solid), water (liquid) and water vapour (gas). Note that in the Figure 2 below the molecules in the solid phase are represented by single spheres, but they would in reality look like the molecules in the liquid and gas phase. Sometimes we represent molecules as single spheres in the solid phase to emphasise the small amount of space between them and to make the drawing simpler.

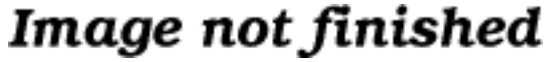

Figure 2: The three phases of matter

Taking water as an example we find that in the solid phase the water molecules have very little energy and can't move away from each other. The molecules are held closely together in a regular pattern called

a *lattice*. If the ice is heated, the energy of the molecules increases. This means that some of the water molecules are able to overcome the intermolecular forces that are holding them together, and the molecules move further apart to form *liquid water*. This is why liquid water is able to flow, because the molecules are more free to move than they were in the solid lattice. If the molecules are heated further, the liquid water will become water vapour, which is a gas. Gas particles have lots of energy and are far away from each other. That is why it is difficult to keep a gas in a specific area! The attractive forces between the particles are very weak and they are only loosely held together. Figure 3 shows the changes in phase that may occur in matter, and the names that describe these processes.

Image not finished

Figure 3: Changes in phase

2 Summary

- There are three states of matter: solid, liquid and gas.
- Diffusion is the movement of particles from a high concentration to a low concentration. Brownian motion is the diffusion of many particles.
- The **kinetic theory of matter** attempts to explain the behaviour of matter in different phases.
- The kinetic theory of matter says that all matter is composed of **particles** which have a certain amount of **energy** which allows them to **move** at different speeds depending on the temperature (energy). There are **spaces** between the particles and also **attractive forces** between particles when they come close together.
- Intramolecular force is the force between the atoms of a molecule, which holds them together. Intermolecular force is a force between molecules, which holds them together.
- Understanding chemical bonds, intermolecular forces and the kinetic theory of matter can help to explain many of the **macroscopic properties** of matter.
- **Melting point** is the temperature at which a *solid* changes its phase to become a *liquid*. The reverse process (change in phase from liquid to solid) is called **freezing**. The stronger the chemical bonds and intermolecular forces in a substance, the higher the melting point will be.
- **Boiling point** is the temperature at which a liquid changes phase to become a gas. The reverse process (change in phase from gas to liquid) is called **condensing**. The stronger the chemical bonds and intermolecular forces in a substance, the higher the boiling point will be.
- **Density** is a measure of the mass of a substance per unit volume.
- **Viscosity** is a measure of how resistant a liquid is to flowing.

3 End of chapter exercises

1. Give one word or term for each of the following descriptions.
   a. The property that determines how easily a liquid flows.
   b. The change in phase from liquid to gas.

   Click here for the solution[1]

[1] http://www.fhsst.org/l2t

2. If one substance A has a melting point that is *lower* than the melting point of substance B, this suggests that...
   a. A will be a liquid at room temperature.
   b. The chemical bonds in substance A are weaker than those in substance B.
   c. The chemical bonds in substance A are stronger than those in substance B.
   d. B will be a gas at room temperature.

   Click here for the solution[2]
3. Boiling point is an important concept to understand.
   a. Define 'boiling point'.
   b. What change in phase takes place when a liquid reaches its boiling point?
   c. What is the boiling point of water?
   d. Use the kinetic theory of matter and your knowledge of intermolecular forces to explain why water changes phase at this temperature.

   Click here for the solution[3]
4. Describe a solid in terms of the kinetic molecular theory.
   Click here for the solution[4]
5. Refer to the table below which gives the melting and boiling points of a number of elements and then answer the questions that follow. (*Data from http://www.chemicalelements.com*)

Element	**Melting point**	**Boiling point ($^{\circ}C$)**
copper	1083	2567
magnesium	650	1107
oxygen	-218,4	-183
carbon	3500	4827
helium	-272	-268,6
sulphur	112,8	444,6

Table 2

   a. What state of matter (i.e. solid, liquid or gas) will each of these elements be in at room temperature?
   b. Which of these elements has the strongest forces between its atoms? Give a reason for your answer.
   c. Which of these elements has the weakest forces between its atoms? Give a reason for your answer.

   Click here for the solution[5]

[2] http://www.fhsst.org/lip
[3] http://www.fhsst.org/lim
[4] http://www.fhsst.org/lgf
[5] http://www.fhsst.org/liy