background sheet

Three states of matter

There are three states of matter: solid; liquid and gas. They have different properties, which can be explained by looking at the arrangement of their particles.

SOLIDS	LIQUIDS	GASES
Solids contain particles arranged in a lattice structure. The particles vibrate in their fixed positions. This explains properties of solids: • They can't be compressed (particles are already tightly packed together). • They keep their shape and have a constant volume when they change container (particles are in fixed positions).	Liquids contain particles that roll around each other and settle on the bottom of their container. The particles are generally slightly further apart than in a solid. (Water is an exception – ice particles are slightly further apart than liquid water, which is why ice floats.) This explains properties of liquids: • They change shape when poured into a different container (particles roll over each other and settle on the bottom). • They have constant volume (particles are close together). • They are slightly compressible. (There are slight spaces between particles.)	Gases contain particles that move around very quickly. The particles travel in straight lines until they bounce off another particle or a surface. Gas particles are widely spaced and tend to be only slightly attracted to each other. This explains properties of a gas: • They fill available space (slight attraction between particles). • They are very compressible (particles are widely spaced).

Absolute zero

This is the theoretical temperature at which particles have the least amount of energy and the slowest movement. It occurs at -273.15 °C, or 0 Kelvin on the scientific temperature scale. Scientists have not been able to cool down any substance to this temperature but have come very close. It used to be thought that particles would stop moving at absolute zero but experiments have shown that this isn't the case.

Particles in motion

All particles are constantly in motion. This is called the kinetic theory of matter. When energy is added to particles (in the form of heat energy for example) they move faster. When energy is removed (for example by cooling) then the particles move slower.

Changing state

Adding or removing energy from particles can cause them to change state. Heating or cooling particles are ways of adding or taking away energy. It causes changes in the arrangement and movement of particles, and can lead to changes in state. There are names for the changes.

TERM	CHANGE IN STATE
melt (melting)	solid to liquid
evaporate (evaporation)	liquid to gas
condense (condensation)	gas to liquid
freeze (freezing)	liquid to solid
sublime (sublimation)	solid to gas
deposit (deposition)	gas to solid

Solutions

A solution forms when a solid (the solute) dissolves in a liquid (the solvent). Although solutions are generally thought of as a solid dissolved in a liquid, both solute and solvent can be any phase: solid, liquid or gas. In this case the solvent is the phase that occurs in the greatest quantity.

PHASES	EXAMPLE SOLUTION
solid in liquid	seawater
liquid in liquid	alcohol in cleaners
gas in liquid	oxygen in water
gas in gas	air
solid in solid	metal alloy, steel (carbon in iron)

Suspensions are a type of mixture in which larger particles are held up or suspended by collisions with the molecules of the liquid or gas that contains them. Particles in a suspension will eventually settle. In a colloid (such as milk or vinaigrette) the distributed particles are so small that they do not settle.

SUSPENSION	COMPONENTS
smoke	ash suspended in air
muddy water	clay suspended in water
fog	water droplets suspended in air

Solubility

Solubility is the defined as mass of solute that can dissolve in a given amount of solvent, at a particular temperature and pressure.

When particles dissolve in a solvent to form a solution they are surrounded by solvent particles, as shown in the learning object *Soft drink science 4: Solutions*. A common misconception is that solute particles wander around in the gaps between solvent particles. This is not the case: there is an interaction between solute and solvent, known as solvation, in which solvent molecules form a solvation shell that surrounds solvent molecules. If the solvent is water this is known as a hydration shell.

Solutions have a saturation point. This is the point when no more solute can dissolve in the solvent and the solution becomes a saturated solution. For some solutes the saturation point varies widely, depending on solvent temperature, for example sugar and water. However other solutes show only a small increase in solubility when temperature increases, for example salt.

Supersaturation

A supersaturated solution forms when a solution contains an amount of solute dissolved in the solvent that is larger than the amount that is usually able to dissolve in a saturated solution. This is tricky to achieve and maintain but can be achieved by heating the solute to a high temperature, adding the solvent to create a saturated solution, then either cooling the solution; increasing the pressure of the solution; or removing some of the solvent through evaporation. Supersaturated solutions are usually very unstable.

Separation techniques

Mixtures and solutions can be separated using physical methods.

TECHNIQUE	APPLICATION
chromatography	separates substances that have different levels of attraction to a solvent
crystallisation	separates dissolved solids from liquids
distillation	separates liquids dissolved in liquids
evaporation	separate liquids from solids that have very high melting points
filtration	separates suspended solids in liquid
nucleation	separates gas from liquids

Particles

Particles in states of matter may be in the form of molecules or ions.

Molecules are particles that are made up of atoms of one or more elements. They can be made up of single atoms, for example helium and argon, or many atoms like sulfur or carbon. Most molecules contain atoms of different elements. For example, a water molecule contains two hydrogen atoms and one oxygen atom; and glucose contains six carbon atoms, twelve hydrogen atoms and six oxygen atoms in each molecule.

Ions are charged particles that have either gained or lost electrons. If they have gained electrons they are negatively-charged particles and if they have lost electrons they are positively-charged particles. In common salt, sodium chloride, each sodium atom loses one electron to form a sodium ion and chlorine atoms each gain an electron to form chloride ions.

More information

The BBC *Bitesize* website has some useful activities. Type a topic (such as 'distillation') into the search box in the top right corner of the page at http://www.bbc.co.uk/schools/gcsebitesize/science.