Chemistry

Big idea (age 11-14)
CPS: Particles and structure

What's the big idea?

11-14:

All matter is made up of atoms. The collective, structural arrangement and behaviour of the atoms explains the properties of different substances.

14-16:

All matter is made up of atomic nuclei and electrons. The behaviour and structural arrangement of atomic nuclei and electrons explains the properties of different materials.

Topics

The big idea is developed through a series of **key concepts** at age 11-14, which have been organised into teaching topics as follows.

The numbering gives some guidance about teaching order based on research evidence on learning pathways and on effective sequencing of ideas. However, the teaching order can be tailored for different classes as appropriate.

11-14:

Topic CPS1
Substances and mixtures

Key concepts:

- CPS1.1 Particle model for the solid, liquid and gas states
- CPS1.2 Particles in solutions

Topic CPS2
Elements and compounds

Key concepts:

- CPS2.1 Atoms and molecules
- CPS2.2 Symbols and formulae

Topic CPS3
Chemical change

Key concepts:

- CPS3.1 Rearrangement of atoms

Topic CPS4
Understanding chemical reactions

Key concepts:

- CPS4.1 Representing reactions
- CPS4.2 Conservation of mass

Topic CPS5
Evaporation

Key concepts:

- CPS5.1 Explaining evaporation

Topic CPS6
Periodic table

Key concepts:

- CPS6.1 Atomic model

14-16:

Topic CPS7
Metallic bonding

Key concepts:

CPS7.1 Metallic structure model

Topic CPS8
Ionic bonding

Key concepts:

CPS8.1 Ionic lattice

Topic CPS9
Covalent bonding

Key concepts:

CPS9.1 Covalent structures

Topic CPS10
Electrolysis

Key concepts:

CPS10.1 Electrolysis of molten compounds

CPS10.2 Electrolysis of solutions

Topic CPS11
Acid, bases and ions

Key concepts:

CPS11.1 Acid and base models

CPS11.2 Concentration, strength and pH

Guidance notes

Chemistry often requires an understanding of both macroscopic observations and a sub-microscopic (particulate) model that explains what is being observed. On other occasions an understanding of the substances involved in the reaction taking place is required. For this reason, several chemistry topics consist of key concepts from more than one big idea. This is shown on key concept map.

Initially at age 11 to 14, a basic particle model is sufficient to explain some properties of substances in the solid, liquid and gas state. This model can be developed to specify the particles as being either (indivisible) atoms or molecules (connected atoms). This model does not allow for an explanation of ions (charged atoms) so at age 11 to 14 this term has not been used.

To understand the 14 to 16 key concepts it is necessary for students to be progress from thinking of atoms as indivisible entities to using the idea of a model of atomic structure in which an atomic nucleus is surrounded by electrons. The idea of ions and also the electrostatic nature of chemical bonding can then be introduced.

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Learning progression

The science story associated with the big idea develops from age 5 to age 16, and could be summarised as follows:

Science story at age 5-11

When a material is looked at it seems to be continuous. Air cannot be seen but it can be felt as wind. Air is a material but cannot be seen because it is made of parts that are too small to be seen, even with a microscope. In fact, all materials are made of parts that are too small to be seen but which can join to create the materials that are visible.

Science story at age 11-14

Particle model

All matter is made up of particles. The arrangement and movement of these particles is described by the particle model. This model can be used to explain observed changes of state. In order to account for differences between the melting and boiling point of substances the particle model must be extended to include consideration of the attractive forces between the particles. The particle model can also explain why a clear solution is formed when a substance dissolves.

Elements and compounds

All matter is made up of atoms. Each element is made up of a different type of atom. A single atom does not have the properties of that element. The properties of an element arise due to the arrangement and behaviour of the atoms collectively. A compound is made up of two or more types of atom joined together. As different atoms are joined than in the separate elements, the compound has properties that are distinct from the elements that are made up of its constituent atoms.

Elements and compounds have one of two types of basic structure. Some are made up of separate groups of two or more atoms (molecules) whereas the atoms in others are joined to make one giant structure. These structures influence properties such as melting and boiling points because there are weaker forces between molecules than within molecules.

The element symbols that form part of a chemical formula represent the types of atom that make up that particular compound. The numbers in a chemical formula show the ratio of these different types of atom. For molecular substances, the number in a formula also gives the number of each type of atom in a molecule.

Chemical change

During a chemical reaction, atoms are rearranged and therefore a new substance (or substances) is formed with different properties to the reactants.

Understanding chemical reactions

Chemical reactions are represented by chemical equations. A word equation summarises the reactants and products of a reaction.

A symbolic chemical equation provides not only qualitative information about the substances in the reaction, but also quantitative information relating to the both the substances and the ratio in which they react. State symbols are used to indicate whether substances are in the solid, liquid or gas state or if they are dissolved in water (aqueous).

For any chemical reaction, the total mass of the reactant substances is equal to the mass of the products. Mass is conserved.

Mass is conserved because during a chemical reaction the atoms are rearranged. No new atoms are created and none are destroyed. A symbolic chemical equation must therefore be balanced so that the number of atoms of each type are the same on both sides of the equation.

If a reaction takes place in an open system and a product is in the gas state, then this product is able to escape. The measured mass will therefore decrease.

Evaporation

The atoms (or molecules) that make up a substance are constantly moving but they do not all have the same kinetic energy. There is a distribution of energies. Some atoms (or molecules) will have enough energy to overcome the forces of attraction holding the atoms (or molecules) together and escape to mix with the air. This allows evaporation to take place below the boiling point of a substance.

Periodic Table

An individual atom is itself made up of even smaller particles. The atomic model describes an atom as consisting of a central nucleus (made up of protons and neutrons) surrounded by electrons.

Science story at age 14-16

Metallic bonding

A simple model of metallic structure is based up on a regular arrangement of positive metal ions surrounded by 'free' outer electrons. In this model, metallic bonding is an all-directional electrostatic force of attraction between the positive ions and negative electrons.

This model can account for simple properties such as why a metal is able to conduct electricity but does not explain why there is variation in the electrical conductivity of different metals. This requires a more sophisticated model.

Ionic bonding

Ionic compounds consist of positively and negatively charged ions that are arranged alternately in a giant structure. This ionic lattice is held together by the electrostatic attraction between oppositely charged ions.

Covalent bonding

Covalent bonds within a molecule and intermolecular forces between molecules are both electrostatic in nature. A giant covalent structure is held together by a large number of covalent bonds. Substances with a giant covalent structure therefore have high melting and boiling points. When a substance made up of separate smaller molecules melts or boils the covalent bonds are not broken. As the intermolecular forces are weaker the melting and boiling points are lower than that of substances with giant covalent structures.

Electrolysis

In the solid state the ions that make up an ionic compound are arranged in fixed positions in the lattice. However, when molten the ions can move. During electrolysis positive ions are attracted to the negative electrode and negative ions are attracted to the positive electrode. Negative ions give up their addition electrons at the positive electrode and become uncharged atoms. Positive ions gain extra electrons at the negative electrode and also become uncharged atoms. Ions are also able to move when an ionic compound is dissolved and so electrolysis of solutions is also possible.

Acids, bases and ions

At age 14 to 16 acids and bases are often defined using the Arrhenius definition. Acids are defined as hydrogen-containing substances which form H^+ ions when they dissolve in water and bases are defined as substances that form OH^- ions. This enables explanation of pH in terms of a scale relating to hydrogen ion concentration and acid strength as a measure of the degree to which hydrogen ions are released when an acid is dissolved in water.

The Arrhenius definition does have limitations, for example in explaining why ammonia (NH_3) is an alkali (soluble base). The Brønsted-Lowry definition of acids and bases refers only to the H^+ ion (proton). Acids are defined as proton donors and bases as proton acceptors.