Molecular geometry

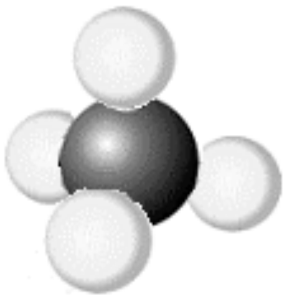
Resources required:
8 sticks of different coloured plasticine (or modelling clay)
per group of 2 to 4 students.

Plato's belief that everything in existence came from perfectly symmetrical solids had some truth. In ancient Greece (about 400 BC), Democritus taught that matter was made of small particles that could not be split in two. These particles were called "atoms".

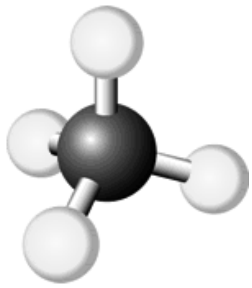
Scientists later discovered that substances are combinations of different elements. They used the word "atom" to mean the smallest uniform particle of an element.

Atoms are treated as if they are spherical. Balls are used as 3D models of atoms. Sometimes a length of stick between the balls is used to represent the distance between the centres of the atoms.

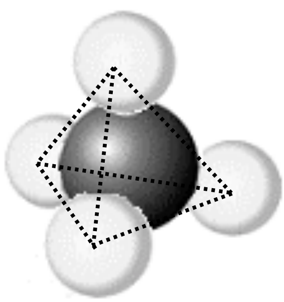
Below is a ball model and a ball and stick model of a molecule of methane gas (CH_4). Four atoms of hydrogen (H) spread themselves evenly around an atom of carbon (C), and each atom of hydrogen is **equidistant** (i.e. the same distance) from the atom of carbon.



A ball model



A ball and stick model



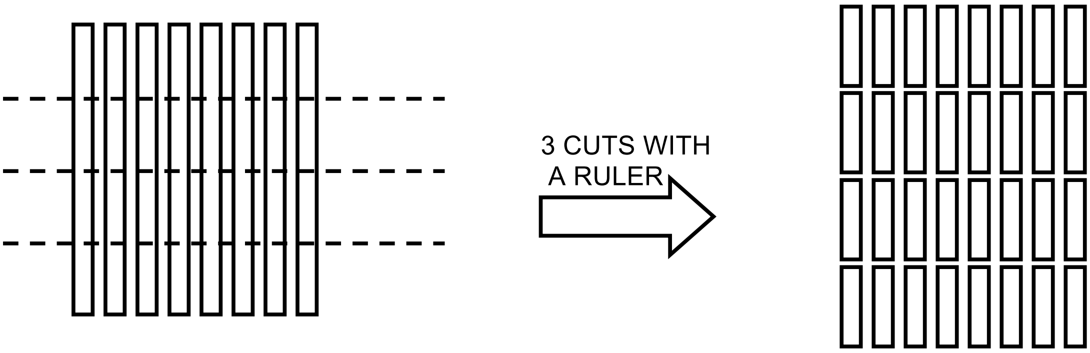
Imagine lines drawn between the centres of the hydrogen atoms.

What 3D shape does this molecule make? ....

The geometric arrangement of the atoms of a substance affects what it is like. For example, the lead in your pencil (called graphite) and a diamond are both made up entirely of carbon atoms. In a diamond, the carbon atoms are in a tetrahedral arrangement. In graphite, the carbon atoms are in layers of hexagonal rings.

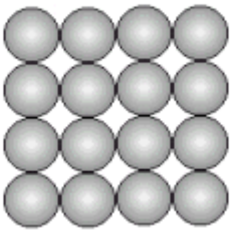
In this activity, you will investigate some ways in which atoms of the same size (atoms of the same element) can be arranged in a solid.

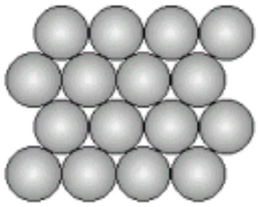
Place your group's 8 sticks of plasticine in a line.
Measure the length of a stick of plasticine.
With a ruler, cut your line of sticks of plasticine into 4 equal pieces.



Mould each piece of plasticine into a small ball between your palms.

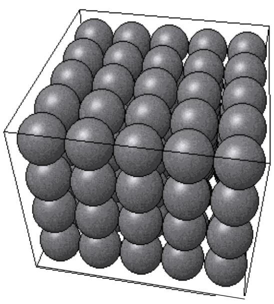
Place your balls to make each of the grids shown below.

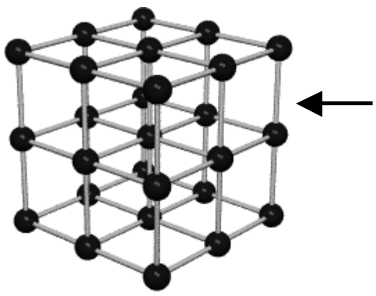

A square grid arrangement


An isometric grid arrangement

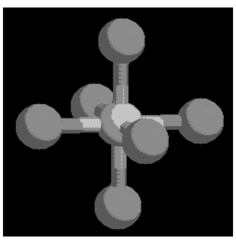
Which arrangement of balls takes up the least space? ....

If you stack balls in a 3 dimensional square grid pattern, the stack looks like the one below. It is called a simple cubic (SC) arrangement.





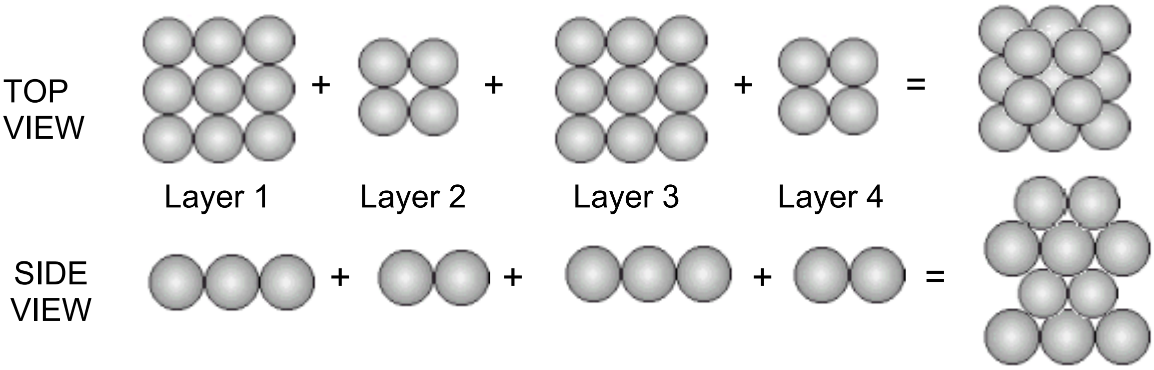
This ball and stick model shows the arrangement more clearly



A central atom is surrounded by how many nearest neighbour atoms (all equidistant from it)? ....

These neighbouring atoms form the vertices of what Platonic solid? ....

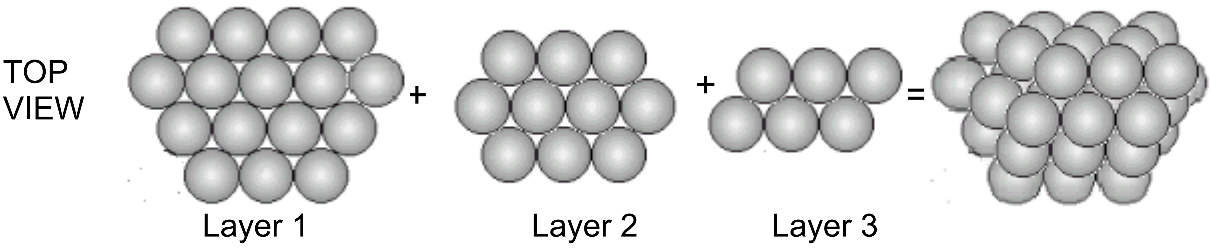
A square grid layer of balls stacked in the depressions of another square grid layer beneath it is called a <u>body-centred cubic</u> (BCC) arrangement.
Make two layers of 3x3 balls and two layers of 2x2 balls.
Push the balls together slightly so they stick to each other.

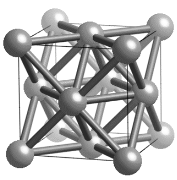


A central atom is surrounded by how many nearest neighbour atoms (all equidistant from it)? ....

These neighbouring atoms form the vertices of what Platonic solid? ....

The closest packing possible is a stacking of isometric grid layers, where each grid layer is stacked in the depressions of the grid layer below it.





This ball and stick model shows the arrangement.
It is called a face-centred cubic (FCC) arrangement.
Can you see how 8 balls form the vertices of a cube?
What Platonic solid do the other 6 balls form?

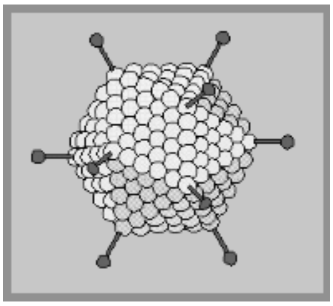
....

Many metals have atoms closely stacked in BCC or FCC arrangements.

Salts are made up of more than one type (and therefore size) of atom, so the arrangements are more complex. The shape of their crystals is determined by the geometrical arrangement of their atoms.

Living Platonic solids

In its basic features, geometry is common to all living systems. Viruses are the simplest form of life. Watson and Crick were the first to point out that the genetic material in small virus particles is probably insufficient to code for more than a few sorts of protein molecules. They predicted that the only reasonable way for these viruses to build a protein shell was for them to make the same type of protein molecule over and over again. This would give them a shell of identical subunits. Subunits need to have an identical environment, so Watson and Crick also predicted that they were packed symmetrically. These predictions were soon confirmed.

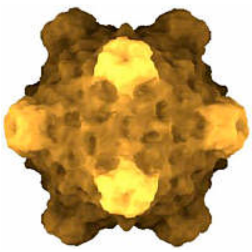


This is an adenovirus that can cause respiratory illness or conjunctivitis.
What Platonic shape is it?

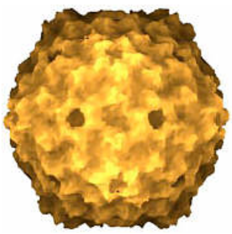
....

Icosahedral symmetry is found in quite unrelated viruses. It is not a matter of chance selection, but a preferred virus structure.

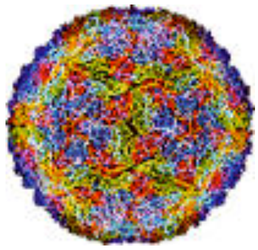
A bacteriophage (a virus of bacteria)



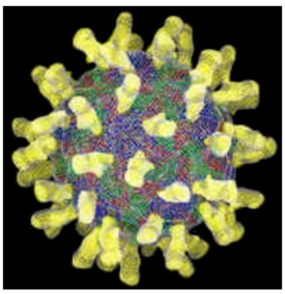
Rice yellow mottle virus (a plant virus)



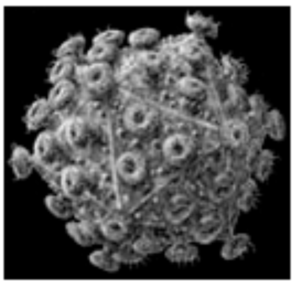
Foot and mouth virus (an animal virus)



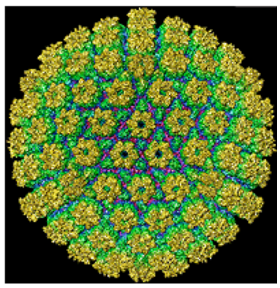
Common cold virus



AIDS virus



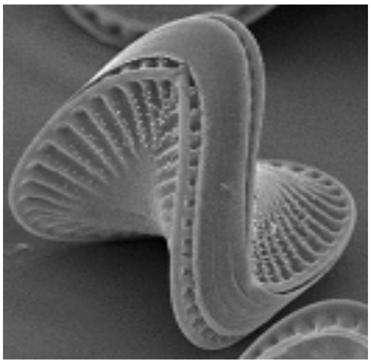
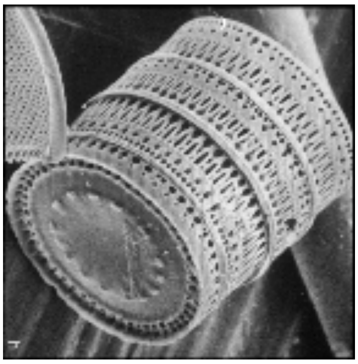
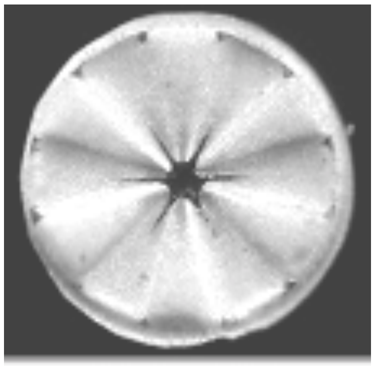
Herpes virus

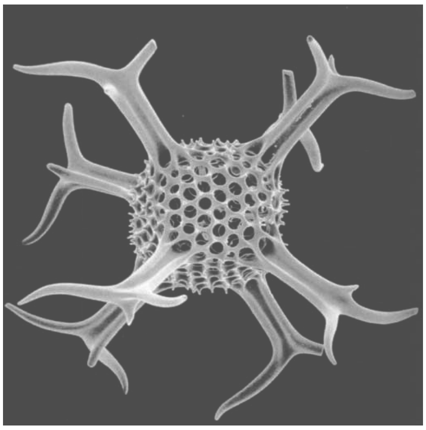
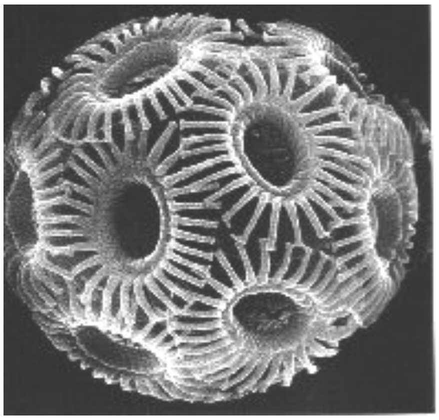


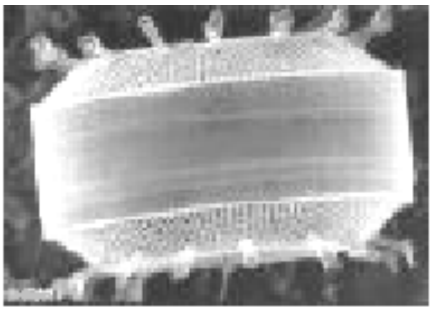
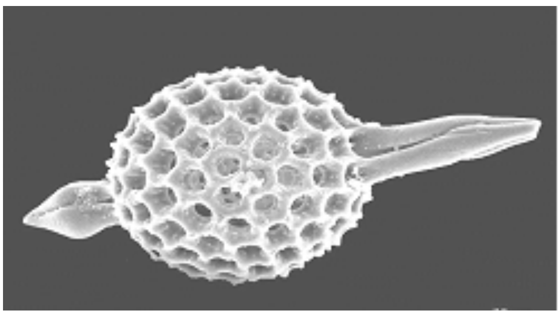
Knowing the shape of a virus, helps scientists search for a suitable vaccine.

Diatoms are another minute marvel of geometrical design. They are a group of microscopic (5 μm to 2 mm wide), single-celled algae that build complex cell walls of silica. They live in water - in the sea, in streams, in lakes and in ditches. They are important because they form the base of food chains and because they reduce the greenhouse effect.

Of the diatoms pictured below, two are shaped like Platonic solids. Write the names of these two shapes underneath their pictures.

Search for more images of viruses and diatoms on the internet and examine their symmetry.

In the space below,
summarise what you have learnt from this chapter, or draw a mind map.

REGULAR POLYHEDRA AND SPHERES