KNOX GRAMMAR SCHOOL

STATE

DA VINCI DECATHLON 2019

CELEBRATING THE ACADEMIC GIFTS OF STUDENTS IN YEARS 7 & 8

da Vinci Decathlon® EXCITE ENRICH CHALLENGE An initiative of Knox Grammar School

SCIENCE

TEAM NUMBER _____

1	2	3	Total	Rank
/19	/15	/16	/50	

Complete the above table with question numbers and marks as required.

1. VOLCANIC ISLANDS

Tahlia was lucky enough to take a trip to Hawai'i with her parents, who are keen amateur geologists. Hawai'i is a cluster of islands that lies in the middle of the Pacific Ocean.

The following pages show several figures. Figure 1 is a map of the largest island in the Hawai'ian cluster, often known as 'Big Island'. Figure 2 shows a more detailed topographic map of the same island and Figure 3 shows how the average annual rainfall varies over the island.

The Hawai'ian islands are relatively young – less than 5 million years old. Each was formed as lava erupted from a crack (or 'hot spot') in the Earth's crust at the bottom of the ocean and gradually built up into a mountain tall enough to emerge from the ocean. Most are extinct, but Big Island currently sits over the hot spot and is still an active volcano.

FIGURE 1: Road map of Big Island, Hawai'i *(image from http://www.hiloagent.com/islandinfo.htm)*

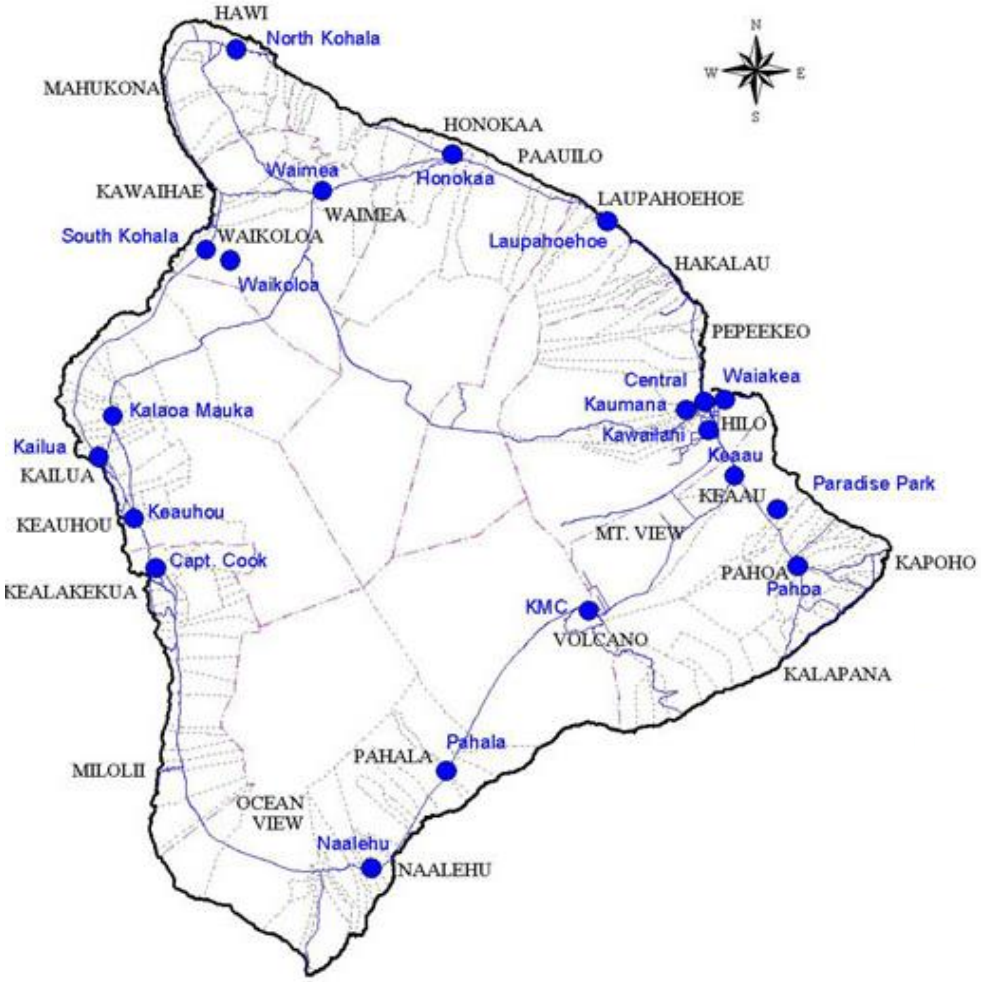


FIGURE 2: Topographic map of Big Island, Hawai'i. The contour lines are equally spaced and show the altitude above sea level marked **in feet** (not metres). 1 foot = 0.305m. *(image from volcano.oregonstate.edu).*

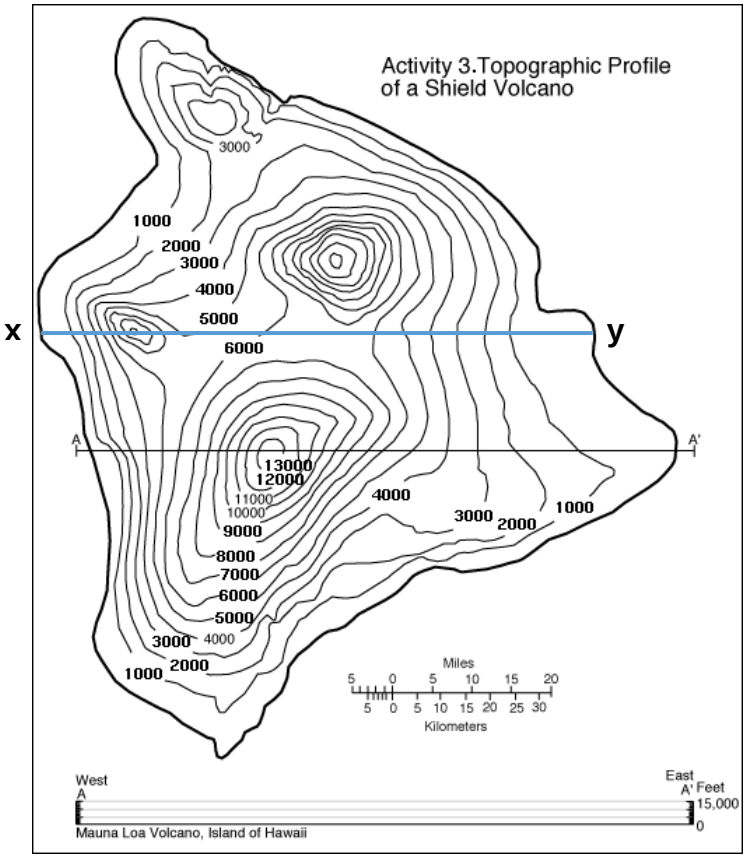
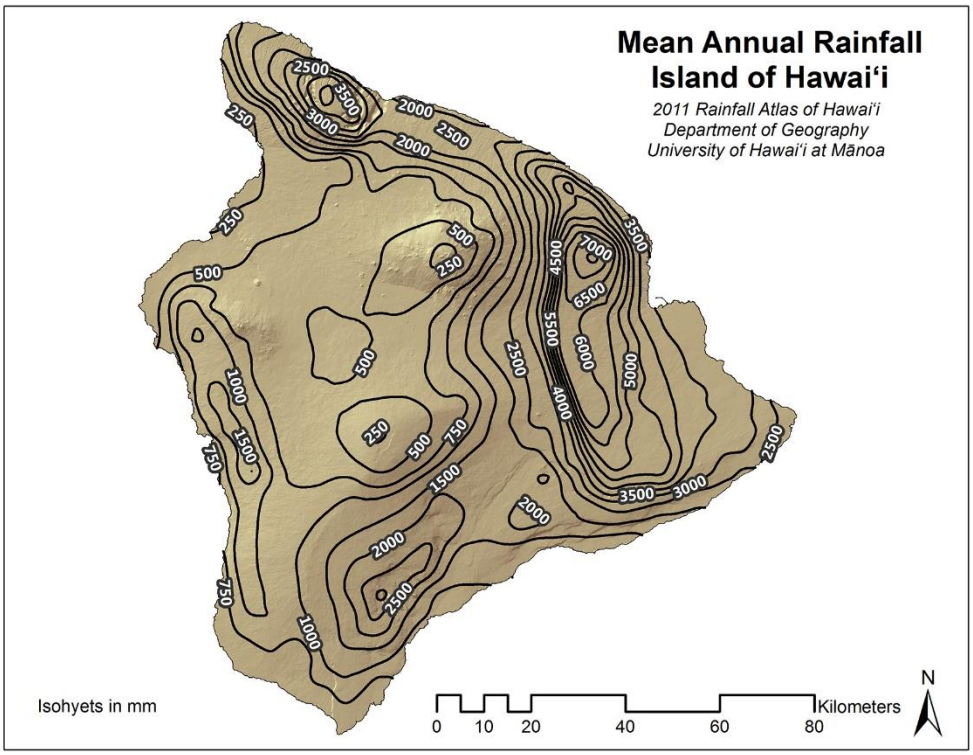


FIGURE 3: Mean annual rainfall map of Big Island, Hawai'i. This map looks like a topographic map, but the lines (called isohyets) instead join regions that have the same annual rainfall (in millimetres of water). For instance, the isohyet closest to the easternmost point of the island indicates areas that have an average of 2500mm (2.5m) of rainfall each year.



a) Look at the following list of rock types. Circle those that are formed by volcanic activity (igneous rocks): [3 marks]

GRANITE; LIMESTONE; QUARTZ; PUMICE; SANDSTONE; OBSIDIAN; MICA; SLATE

Tahlia discovers that Hawai'ian beach sand is quite different to Australian beach sand. Black, red and green beaches on Hawai'i have sand formed by the erosion of igneous rocks from nearby volcanoes. The white sand beaches on Hawai'i are entirely made from calcium carbonate, which is biological in origin.

The sand on Australian beaches (usually white or yellowish) is mostly composed of silica quartz fragments, with some calcium carbonate. Sand made of quartz is generally very old: the fragments may have broken away from their source rocks millions or even hundreds of millions of years ago and may have been through several sedimentary and weathering cycles.

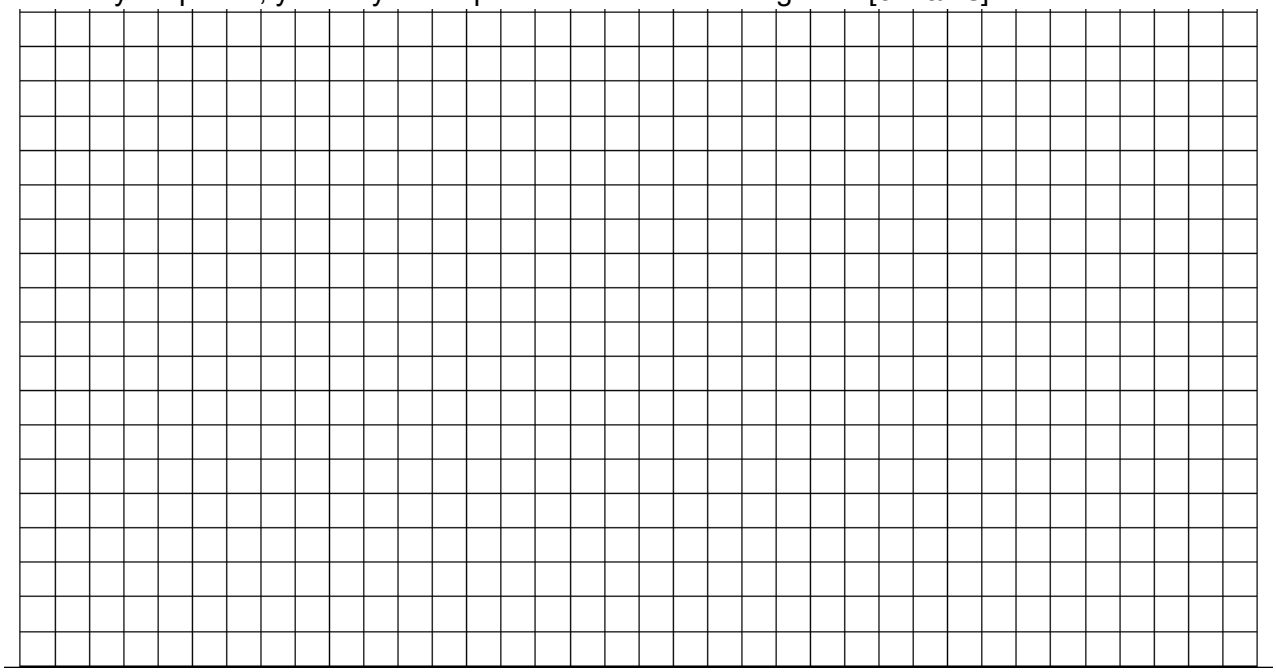
b) Propose an explanation for the difference in the composition of white sand in Australia and Hawai'i. [3 marks]

c) Figure 2 is a topographic map of Big Island. Topographic maps use 'contour lines' to show where high and low points are. Each contour line joins locations on the map that have the same altitude. Hence, if Tahlia were to walk *along* a contour line on the actual landscape, she would be walking a level path. If she walked *across* contour lines, she would be moving from one height to another, so she would be going uphill or downhill.

Using the grid below, draw a **profile** of the land Tahlia would cross if she were to hike east across the island in a straight line from the coast at point X to the coast at point Y (marked on Figure 2).

Note: a profile is like a side-view of the land. To draw a profile, make 'distance' (in km) the x-axis of your graph, and 'altitude' (in feet) the y-axis. The graph will then show how the altitude changes as Tahlia travels across the island. Your graph must be to scale, but the horizontal and vertical scales may be different.

Use the working space on the following page for your scale calculations. Even if you don't finish your profile, you may score partial marks for working. [6 marks]



(Working space.)

d) Use Figures 1, 2 and 3 for this question. [4 marks]

i. Identify the town (marked with a dot) with the lowest annual rainfall:_____

ii. Estimate the altitude of Waimea (in the north):_____

iii. Estimate the annual rainfall at Pahoa (south of Hilo):_____

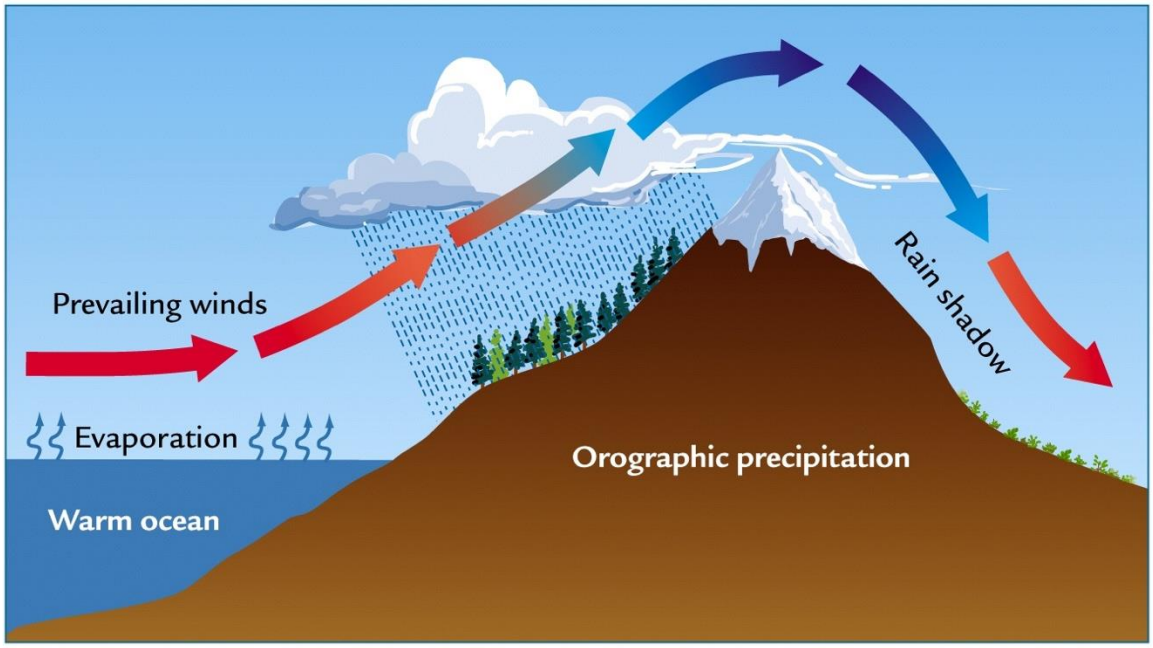
iv. When a volcano erupts, it usually forms a cone-shaped peak. Big Island is made up of more than one volcano. Study the topographic and road maps and state how many volcanoes are on Big Island:

_____

e) Study the rainfall map (Figure 3) carefully. Among other things, it indicates high rainfall on the east of the island. In Hawai'i, the winds usually blow from the east.

Write a dot point explanation for the pattern of rainfall on Big Island. You may use Figure 4 below to aid you. Incorporate as much science into your explanation as possible. [3 marks]

FIGURE 4: Orographic precipitation (mountain rainfall).



http://web.sonoma.edu/users/f/freidel/global/372lec2images.htm

2. MOONSCAPES

Over the last fifty years, humankind has constructed many remotely controlled space probes to allow us to explore, view and sample the landscapes of other planets and moons in the Solar System.

The Cassini probe explored Saturn and Jupiter between 1997 and 2017. One of its activities was a flyby in 2015 of the moon Enceladus.

Enceladus is an icy moon that orbits Saturn at a distance of 240 000km. It was discovered that huge plumes of gas were being emitted from cracks in the ice at its south pole, and one of the objectives of Cassini's flyby was to sample the gas in these plumes to determine what was in it.

Enceladus has a radius of approximately 250km. Various measurements suggest that the moon consists of a rocky core, perhaps like the Earth's, completely covered in a 10 km deep ocean that lies beneath a layer of ice. The ice crust is estimated to have an average thickness of 25 km, although around the south pole, where the plumes emerge, the ice is thought to be as little as 1km thick.

Temperature mapping of the surface of Enceladus shows that the area around these cracks is warmer than the rest of the moon, and scientists have suggested that there are geothermal vents located on the ocean floor at this location.

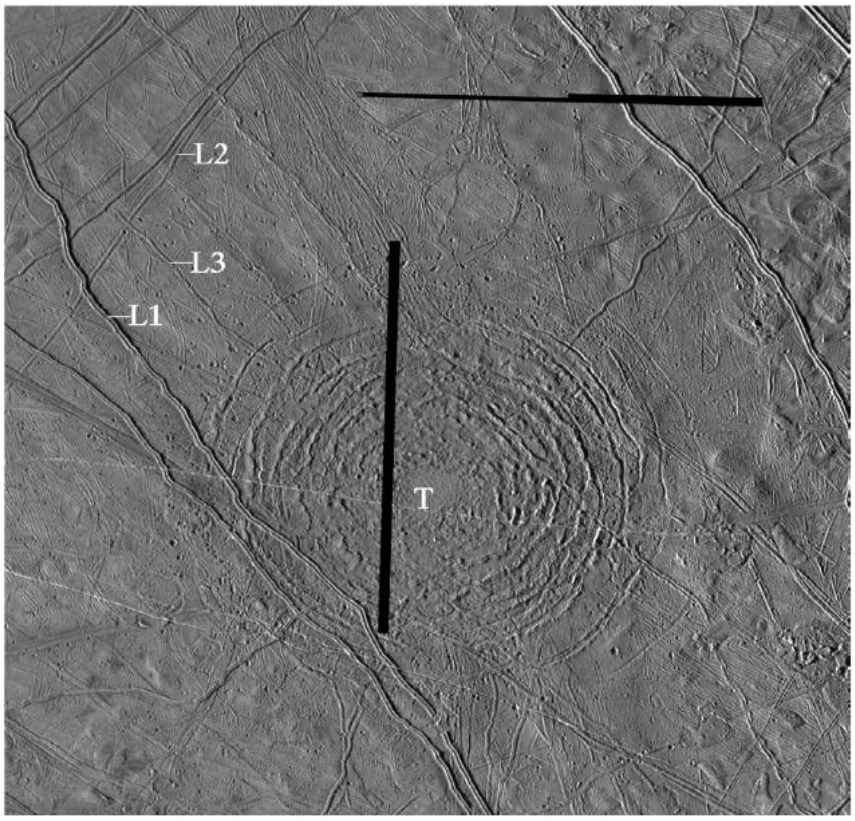
a) Draw a neat, labelled diagram of Enceladus incorporating the information above. You do not need to include Saturn in your diagram. The diagram does not have to be to scale. Use the space on the next page. [4 marks]

b) Using the information above, and assuming Enceladus is spherical, calculate the minimum and maximum volume of water contained within the ocean of Enceladus, where the Volume of a sphere = $V = \frac{4}{3}\pi r^3$. [3 marks]

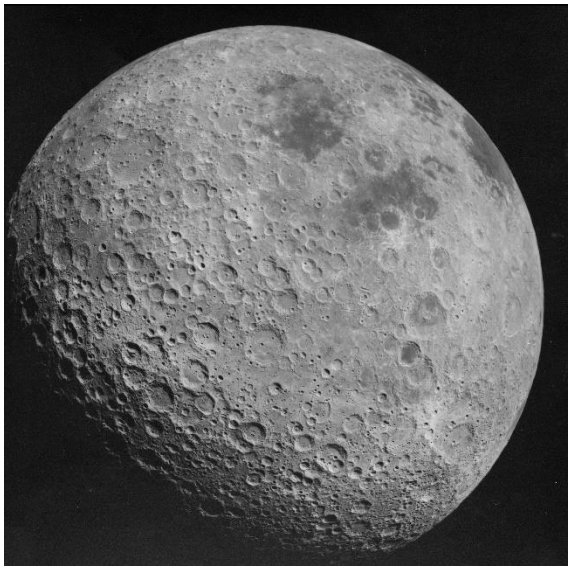
DIAGRAM OF ENCELADUS

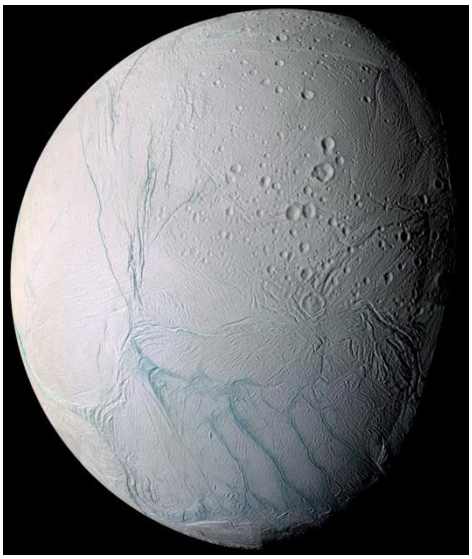
Europa is one of the moons of Jupiter. Like Enceladus, it is thought to have a liquid ocean beneath an ice layer and is observed to emit gas plumes. Also like Enceladus, its surface is covered in cracks and streaks. These are believed to arise from tectonic movements causing the ice crust to crack. Liquid water then wells up and refreezes.

The image below was taken by the Galileo spacecraft as it passed Europa in 1998. The structure marked T with the broken concentric rings is known as the 'Tyre' structure. Three linear features (cracks) are marked L1, L2 and L3. (Note: The black lines are areas of missing data.)



c) Study the picture carefully, and list the structures L1, L2, L3 and T in order of age, from youngest to oldest. Give reasons for your answer. [4 marks]





Earth's Moon (above left) has a radius of about 1400km and orbits Earth at a distance of 380 000km. It is tidally locked, meaning the same side of the Moon always faces us. Its entire surface (which is dusty and rocky) is pockmarked with impact craters caused by meteorites.

Enceladus (above right) orbits Saturn at a distance of 240 000km and is also tidally locked. It looks quite different to the Moon. While it has a lot of impact craters in the north, other regions, particularly the South Polar Region, are almost entirely free of them.

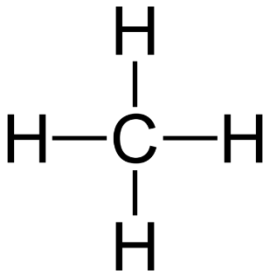
Alex is studying moons in Earth Science at school. His teacher asks the students to consider the idea that perhaps the crater-free region of Enceladus is 'shaded' from meteorite impacts by Saturn. They decide that this is unlikely, because Enceladus is not so different from the Moon, and is also tidally locked, so if Saturn were shading Enceladus we would expect to also see some shading from the Earth on the Moon.

d) Based on the information provided, propose another reason why no craters are visible in the south polar region of Enceladus. [3 marks]

3. MOLECULAR LANDSCAPES

When Cassini sampled Enceladus' gas plume, it was able to detect a range of molecules. Much of the plume was water, but hydrogen, carbon monoxide and some larger molecules were also present. The larger molecules were mostly made of carbon and hydrogen atoms joined together – these kinds of molecule are known as **hydrocarbons**.

The simplest hydrocarbon is methane, made of one carbon and four hydrogen atoms. It can be represented like this:

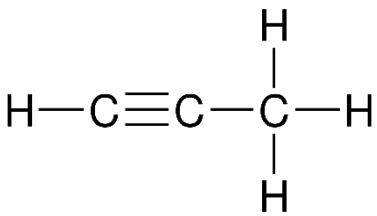


'C' is the symbol for a carbon atom and 'H' is the symbol for a hydrogen atom. The lines between the letters represent chemical **bonds,** which hold the atoms together as a molecule.

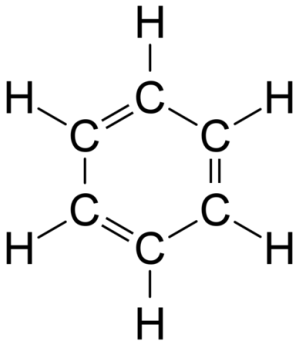
The rules that govern how carbon and hydrogen atoms form molecules are:

1. *Each carbon atom must form exactly four bonds. These may be with other carbon atoms or with other types of atom.*
2. *The four bonds can be made up of a combination of single, double or triple bonds.*
3. *Hydrogen atoms form only one bond each.*

Inspect the following diagrams to see different ways in which these rules can be satisfied.



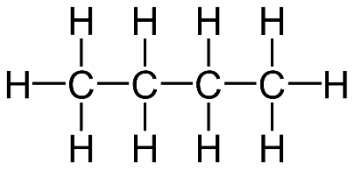
This molecule contains three carbon atoms and four hydrogen atoms. It has a triple bond (three bonds) between two of the carbon atoms.

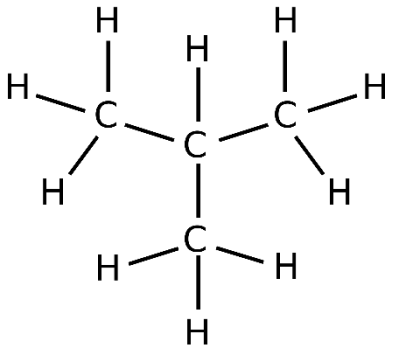


This molecule contains six carbon atoms in a ring, with six hydrogen atoms. Every second pair of carbon atoms is joined by a double bond.

When the instruments on Cassini detected organic molecules, they were only able to detect the number and type of atoms in each molecule, but not the way in which they were attached to each other. This means some detective work is needed, because there may be more than one way for the atoms to be attached together.

For instance, if a scientist knew that a molecule contained four carbon atoms and ten hydrogen atoms, there are only two distinct ways in which they could be arranged (bearing the above rules in mind):





These two molecules have the same number and type of atoms, but different structures. They are called **isomers**. Note that the angles between the bonds in your drawing doesn't matter. The important thing is to check that the way in which the atoms are connected is different.

The more atoms you have to play with, the more isomers are possible. Scientists have to consider a whole landscape of molecules when sorting out problems like this.

a) If you know you have a molecule that contains five carbon atoms and twelve hydrogen atoms, there are three possible isomers it could be. Draw their structures below. [6 marks]

b) Draw as many isomers as possible for a molecule that has five carbon atoms and ten hydrogen atoms. Hint: not all of them have a double bond. [10 marks]

END OF PAPER