Raffles Girls' School (Sec.)

Raffles Academy Chem!stry

Name: ……………………… ( )

Class: …………

Date: ……… / ……… / ………

Single Molecule's Stunning Image

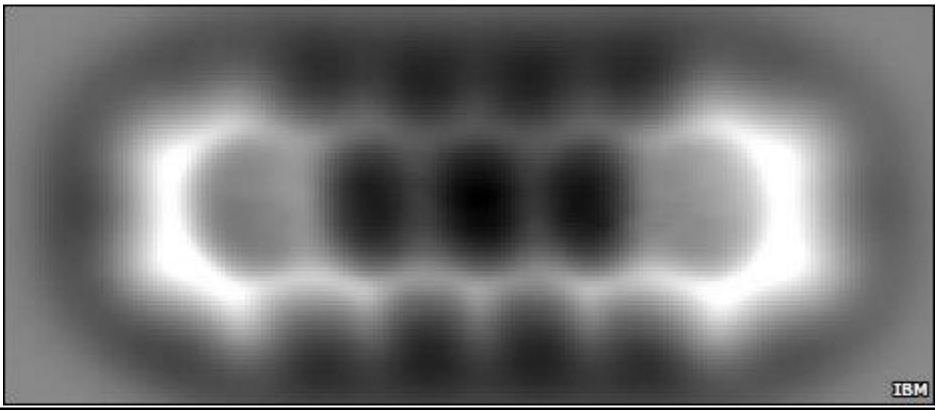

Figure 1.
Image of the pentacene molecule that was obtained by IBM Research Zurich.

The detailed chemical structure of a single molecule has been imaged for the first time, say researchers. The physical shape of single carbon nanotubes has been outlined before, using similar techniques – but the new method even shows up chemical bonds. Understanding structure on this scale could help in the design of many things on the molecular scale, particularly electronics or even drugs. The IBM researchers report their findings in the journal Science. It is the same group that in July reported the feat of measuring the charge on a single atom.

In both cases, a team from IBM Research Zurich used what is known as an atomic force microscope or AFM. Their version of the device acts like a tiny tuning fork, with one of the prongs of the fork passing incredibly close to the sample and the other farther away. When the fork is set vibrating, the prong nearest the sample will experience a minuscule shift in the frequency of its vibration, simply because it is getting close to the molecule. Comparing the frequencies of the two prongs gives a measure of just how close the nearer prong is, effectively mapping out the molecule's structure. The measurement requires extremes of precision. Consequently, the whole setup has to be kept under high vacuum and at blisteringly cold temperatures. However, the tip of the AFM's prong is not well-defined and isn't necessarily sharp on the scale of single atoms. The effect of this bluntness is to blur the instrument's images. The researchers have now hit on the idea of deliberately picking up just one small molecule – made of one atom of carbon and one of oxygen – with the AFM tip, forming the sharpest, most well-defined tip possible. Their measurement of a pentacene molecule using this carbon monoxide tip shows the bonds between the carbon atoms in five linked rings, and even suggests the bonds to the hydrogen atoms at the molecule's periphery.

Lead author of the research Leo Gross told BBC News that the group is aiming to combine their ability to measure individual charges with the new technique, characterising molecules at a truly unprecedented level of detail. That will help in particular in the field of "molecular electronics", a potential future for electronics in which individual molecules serve as switches and transistors. Although the approach can trace out the ethereal bonds that connect atoms, it cannot distinguish between atoms of different types.

The team aims to use the new technique in tandem with a similar one known as scanning tunnelling microscopy – in which a tiny voltage is applied across the sample – to determine if the two methods in combination can deduce the nature of each atom in the AFM images. That would help the entire field of chemistry, in particular the synthetic chemistry used for drug design. The results are of wide interest to others who study the nano-world with similar instruments. For them, implementing the same approach is as simple as picking up one of these carbon monoxide molecules with their AFM before taking a measurement.

Article published by the BBC NEWS: 28th August 2009
http://news.bbc.co.uk/go/pr/fr/-/2/hi/science/nature/8225491.stm

Questions

a) Clearly and concisely explain what scientific achievement Leo Gross and his team of researchers have made through their pioneering work:

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[2]

b) A technique similar to the one used by researchers in this paper has been used to define the shape of carbon nanotubes (line 2). What is a carbon nanotube?

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……..

[1]

c) **"**It is the same group that in July reported the feat of measuring the charge on a single atom" (line 6). Briefly explain why this sentence could be interpreted as being scientifically incorrect:

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[1]

d) **"**The measurement requires extremes of precision" (lines 12–13). Explain how the use of a vacuum and a very low temperature allow the scientists to achieve extremely high levels of precision in their experiment:

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[2]

e) Pentacene has the formula $C_{22}H_{14}$. Use this information, along with information found in lines 18–19 and **Figure 1**, to draw the structure of a pentacene molecule:

[2]

f) Explain the advantage of using an atomic force microscope with a tip made from a single molecule of carbon monoxide:

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[1]

g) Draw a clear dot (•) and cross (×) diagram to show the arrangement of the electrons, and hence the bonding, in a single molecule of carbon monoxide:

[1]

h) Although the atomic force microscope designed by the scientists is able to show the structure of a molecule in unprecedented detail, what is it unable to do that would be of great interest to chemists?

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[1]