

# ***Basics 2: Big Molecules***

## Not So Fast

So the world seems simple. There are elements and compounds. Elements are composed of one kind of atom, and compounds contain more than one kind of atom.

When two or more atoms are bonded together, you have a molecule. Elements can come as molecules: hydrogen, oxygen, nitrogen, fluorine, chlorine, bromine, and iodine, for example, are all found in nature as diatomic molecules. The world is simple, right?

Well, as usual, we can count on nature to frustrate our classification schemes whenever she gets the chance.

What follows are a few examples of this kind of frustration.

## Polymers

Atoms can form into giant molecules called polymers. While these do not differ conceptually from the smaller molecules with which we are now familiar, there is an important distinction: in a polymeric substance, the molecules can have many different sizes, thereby differing from our previous view that one compound exactly corresponds to one kind of molecule.

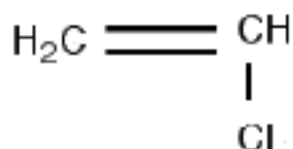
Polymers are like giant chains made from individual links. The links are all the same (or at least they are similar) and are called monomers.

Polyvinyl chloride (PVC), a common plastic, used in, among other things, plumbing, is made from the monomer styrene.

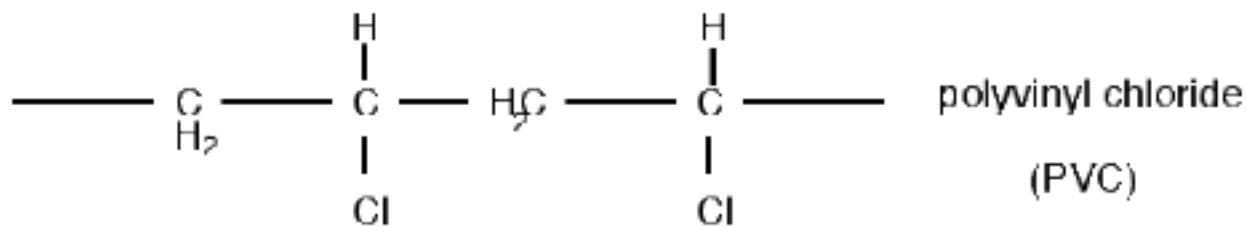
In the drawing below, we show first the monomer for PVC, a vinyl chloride molecule. Below that we see the polymer...well....really not the whole thing...that would be billions of monomers long. (That is why we call it a macromolecule.) Instead we show just two of the monomers stuck together with question marks at each end, signifying that we don't know for sure how long the chain goes on...we just know it keeps going and going and going.....

By the way, if you are wondering what happened to the double bond, it becomes the "hand" that is stretched out at each end to other vinyl chloride monomers.

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vinyl chloride



polyvinyl chloride  
(PVC)

## Networks

Network compounds are similar to polymers in that they are **covalently bonded** and contain huge numbers of atoms. Networks differ because they, in general, have a better defined geometric structure and the structure is not linear but three-dimensional. In addition, the structure of a network is the entire solid particle. A diamond, for example consists of one diamond "molecule". It is not a molecule in the traditional sense, because it is unlikely that any two diamonds will have the same number of atoms in them. These structures are often called macromolecules. Silicon dioxide, known colloquially as quartz, is an example of a network solid and we show diagrammatically what we mean below.

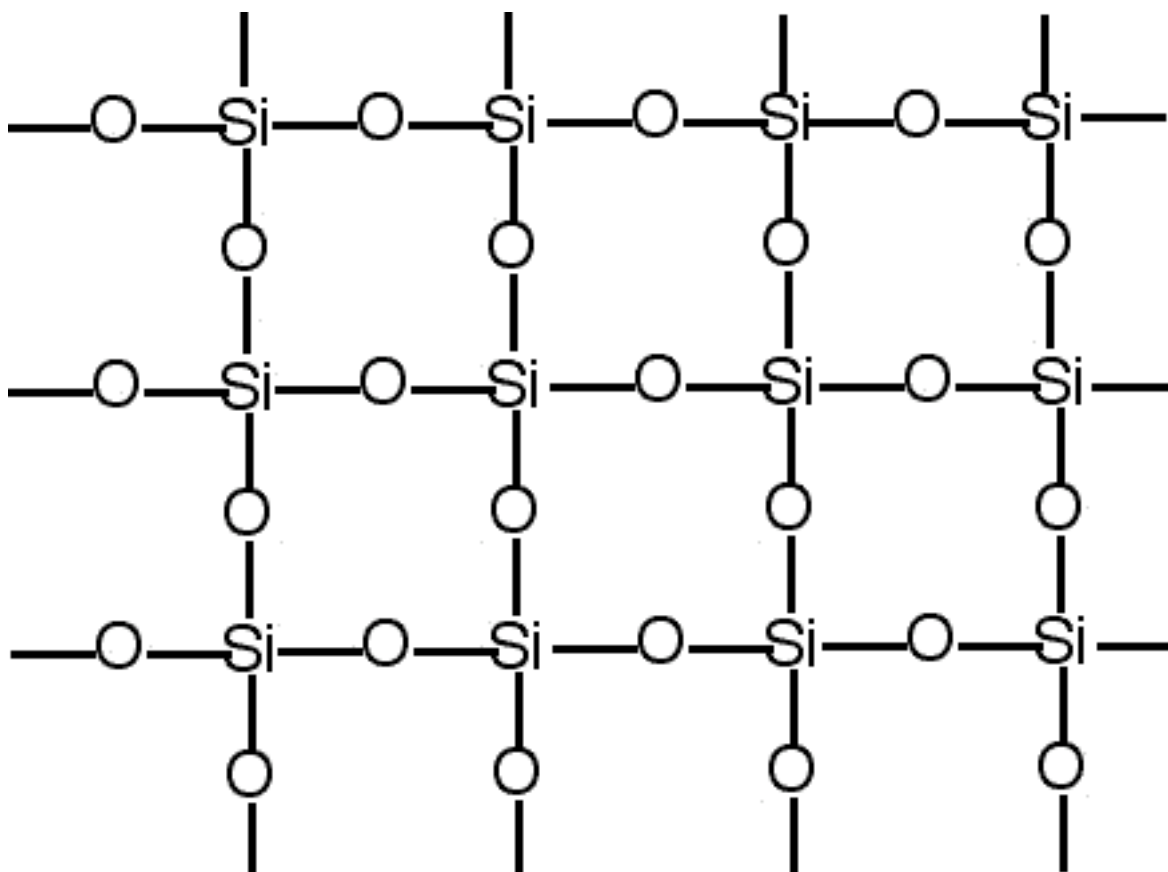
Note that our diagram is flawed because we show it in only 2-dimensions whereas the actual structure is a 3D one. Still, this gives you some idea of what we mean by a network: just imagine it coming out of the screen at you, and you are there.

When we write the formula for silicon dioxide (or for any macromolecule) we write down the "least common denominator" the smallest sub unit which is repeated over and over again.

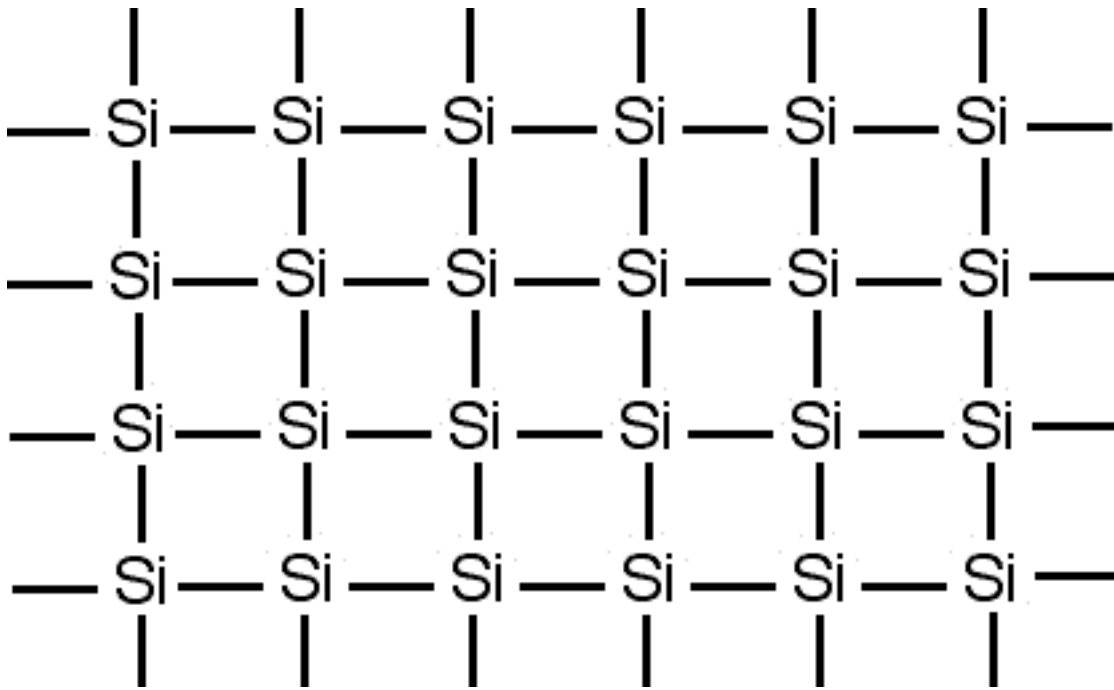
Thus, even though there are billions and billions of atoms in the tiniest fleck of quartz, we still refer to it as  $\text{SiO}_2$ .

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Covalent Bonds are bonds in which atoms share electrons. These electrons are located between the atoms and hold them together. See more about this in the bonding section.



Elements can also exist as network solids. Diamond, which is nothing more than elemental carbon is an example of a covalent network. Elemental silicon also comes to us in this way and we illustrate its network properties in the diagram below:

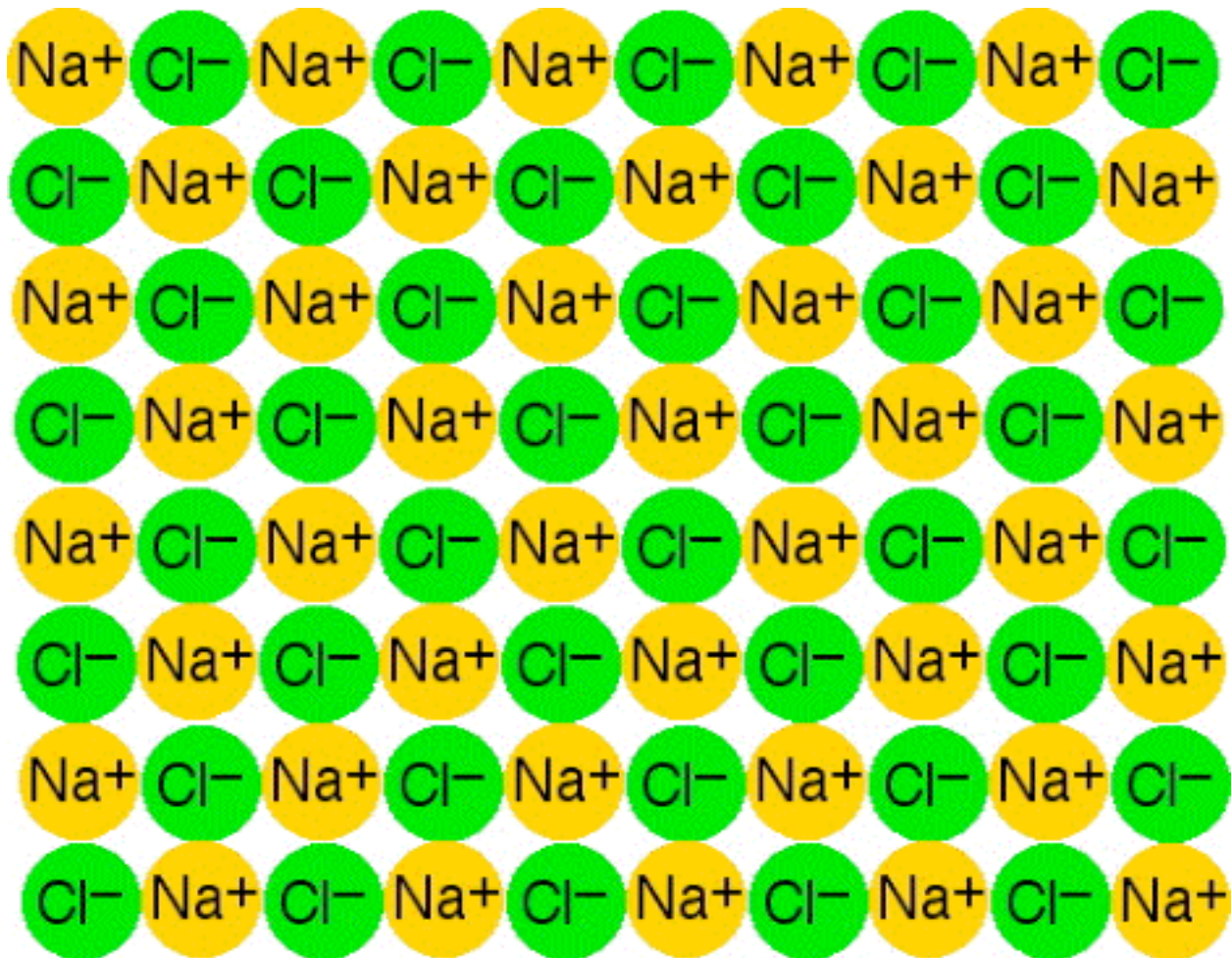


## Ionic Compounds

Ionic compounds are inherently macromolecular. Ionic compounds are held together by ionic bonds. You get an ionic bond when a positively charged ion is attracted to a negatively charged ion as illustrated below:



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But the positively charged ion will attract not just one negative ion, but ALL the negatively charged ions in the neighborhood, and any negative ion will try likewise to surround itself with positive ions. Thus it is usually impossible to talk about an isolated NaCl molecule...such a thing can exist...but in almost all situations, you get an extended ionic solid, illustrated (again imperfectly because the real thing is 3D) below:

As a result, we don't generally speak of a molecule of sodium chloride (these CAN exist, but only under very special conditions).

## Metallic Substances

In a sample of a metal, all the atoms are bonded to their neighbors via metallic bonds. Again, we have bonds and so we think "molecule" (don't worry yet about what a metallic bond is). But we don't have a molecule, but a giant hunk of atoms all stuck together. Every time you tear off a different sized hunk of aluminum foil, you are creating a new metal "mega-molecule" with some arbitrary and large number of atoms in it. For this reason, we also don't think of metal structures as conventional molecules.

## So What Shall We Call Them?

We need a name for these large structures and so we will call them **macromolecules**. I don't know if every chemist would agree with the way I am applying this term, but I think it works and makes its point. We generally observe macromolecules in the composition of the following kinds of substances:

- polymers
- network solids
- ionic compounds
- metals