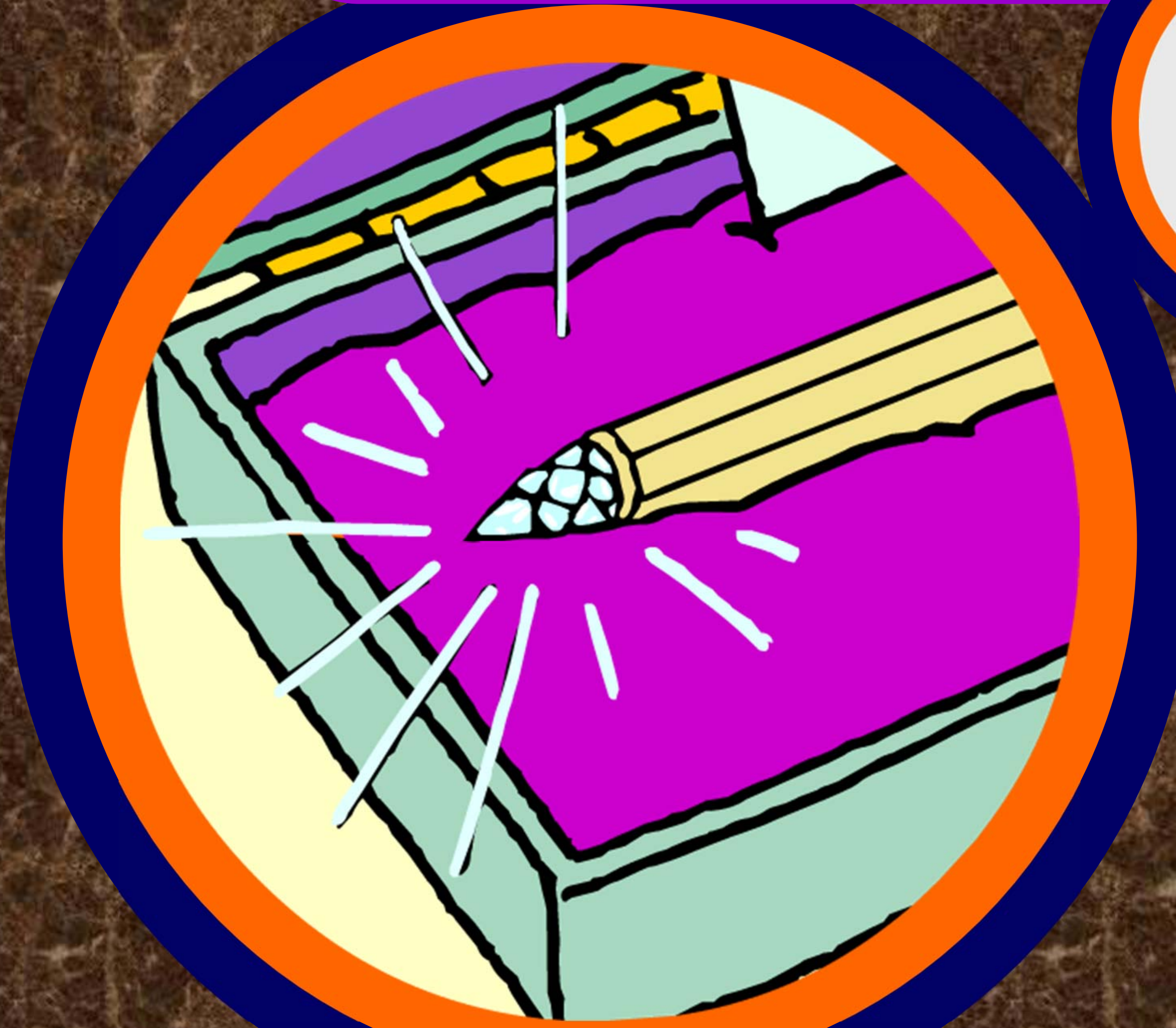
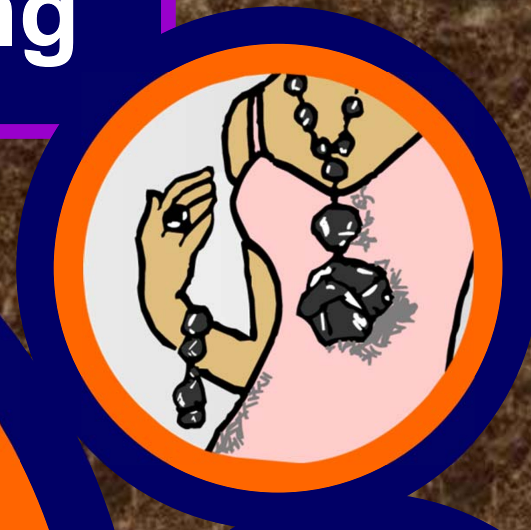
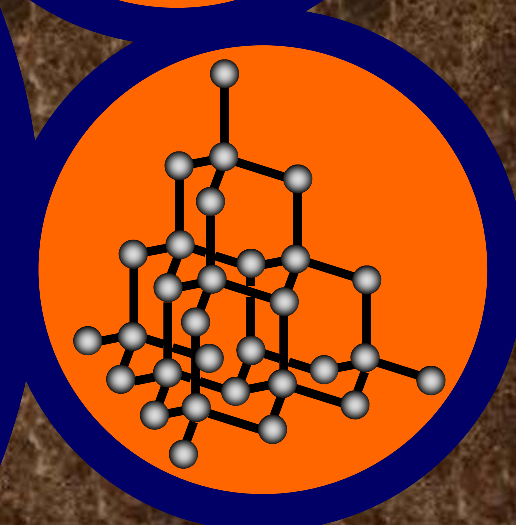
Covalent Bonding





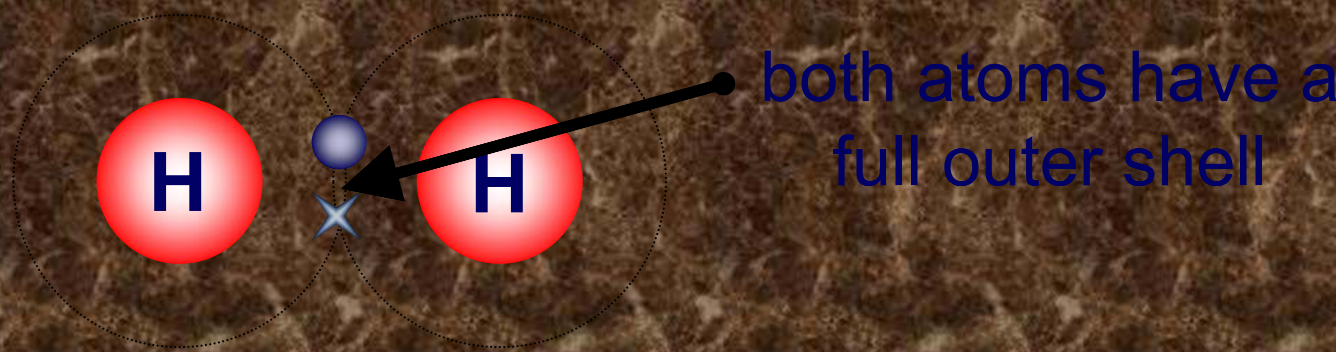


Covalent bonding in elements

The covalent bond

- When non-metal atoms react together, they need to gain electrons to fill their outer shell and become stable.

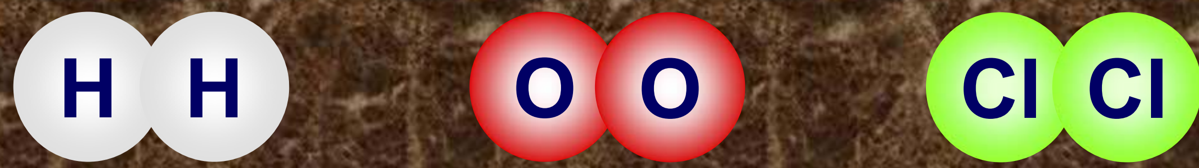
They can only do this if they **share** electrons with each other.



The atoms share electrons so there is a strong force that joins the atoms together. This is called a **covalent bond**.

Covalent bonding and elements

- Many elements exist as **molecules** – two or more atoms joined by a covalent bond. Each atom has a full outer electron shell and is therefore stable.



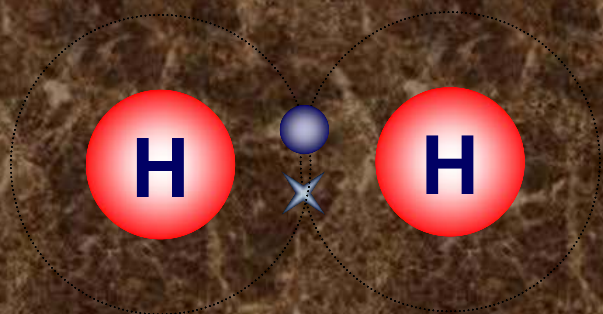
- Only the outer shell of electrons is involved in covalent bonding. This means that the inner shells do not always have to be included in diagrams.

Two common ways to indicate a covalent bond are:

solid line

H–H

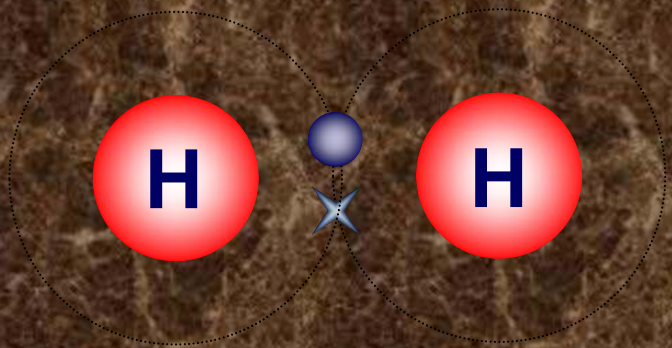
dot and cross diagram



Covalent bonding in hydrogen

- Hydrogen (electron configuration: 1) needs 1 more electron to have a completely full outer shell.

To achieve this, it can share an electron with another hydrogen atom. This creates a **single bond** and the two hydrogen atoms form a hydrogen molecule.



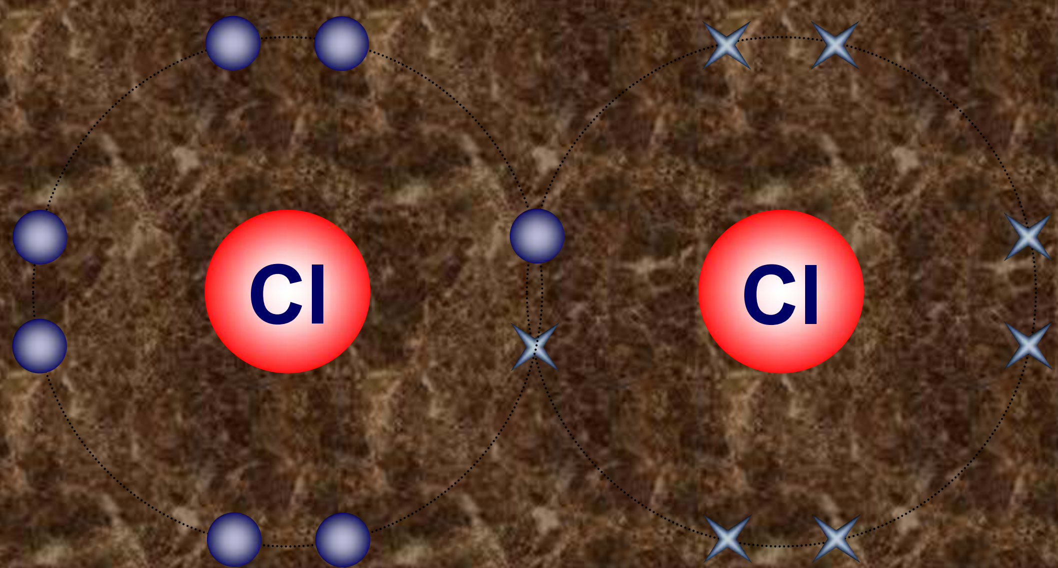
H_2 or H–H

There are two atoms in the molecule so it is called **diatomic**.

Covalent bonding in chlorine

- Chlorine (2.8.7) needs 1 more electron to have a completely full outer shell.

To achieve this, it can share an electron with another chlorine atom. This creates a single bond.

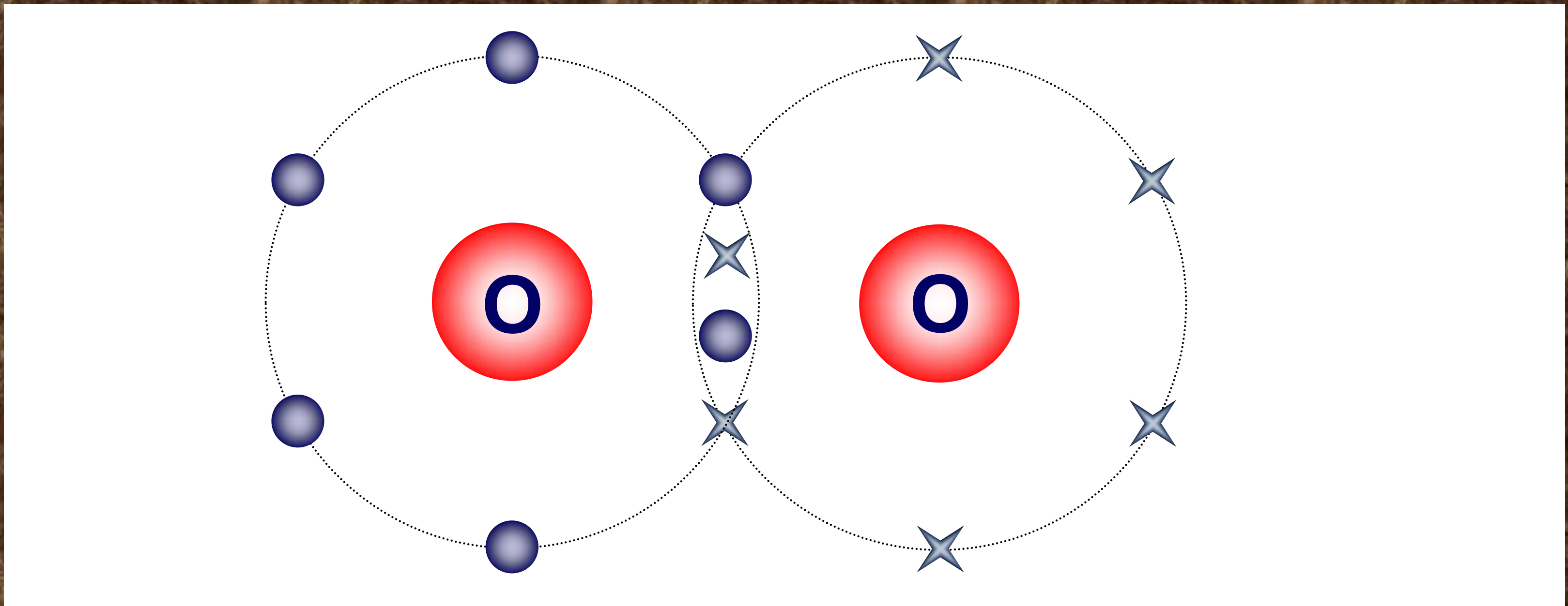


Cl_2 or Cl–Cl

Covalent bonding in oxygen

- Oxygen (2.6) needs 2 more electrons to have a completely full outer shell.

To achieve this, it can share two electrons with another oxygen atom. This creates a **double bond**.

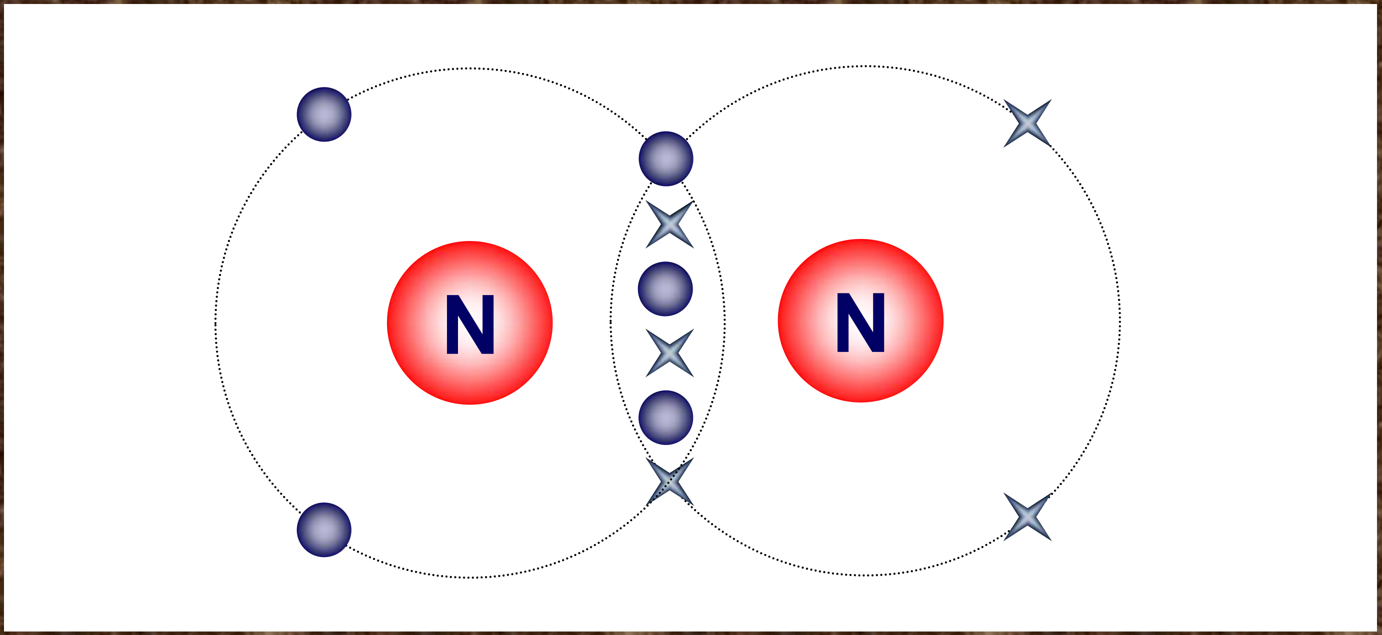


O_2 or O=O

Covalent bonding in nitrogen

- Nitrogen (2.5) needs 3 more electrons to have a completely full outer shell.

  It can share three electrons with another nitrogen atom to do this. This creates a **triple bond**.



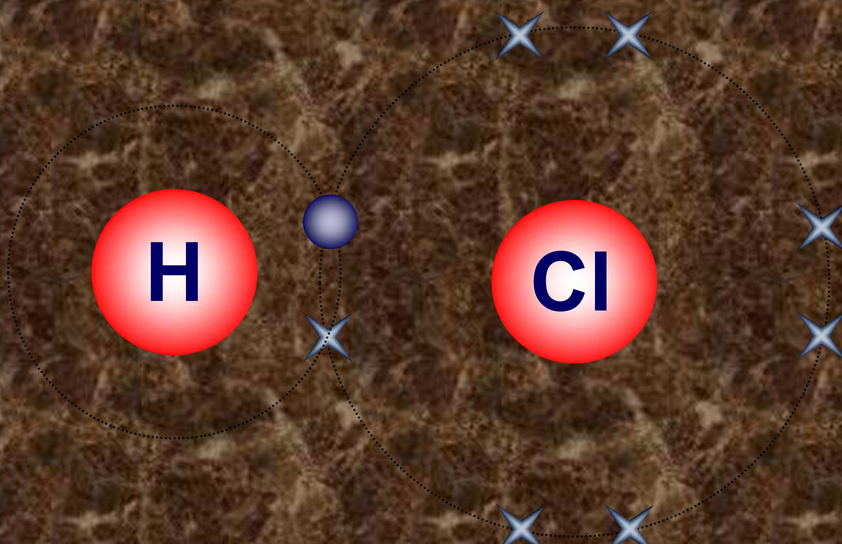
N_2 or N≡N

Covalent bonding in compounds

Covalent bonding in compounds

- Covalent bonding can take place between atoms of different elements to create molecules of **covalent compounds**. These covalent bonds can be single, double or triple.

Both hydrogen (1) and chlorine (2.8.7) need 1 more electron to fill their outer shell. By sharing one electron each, they can fill their outer shells and become stable.

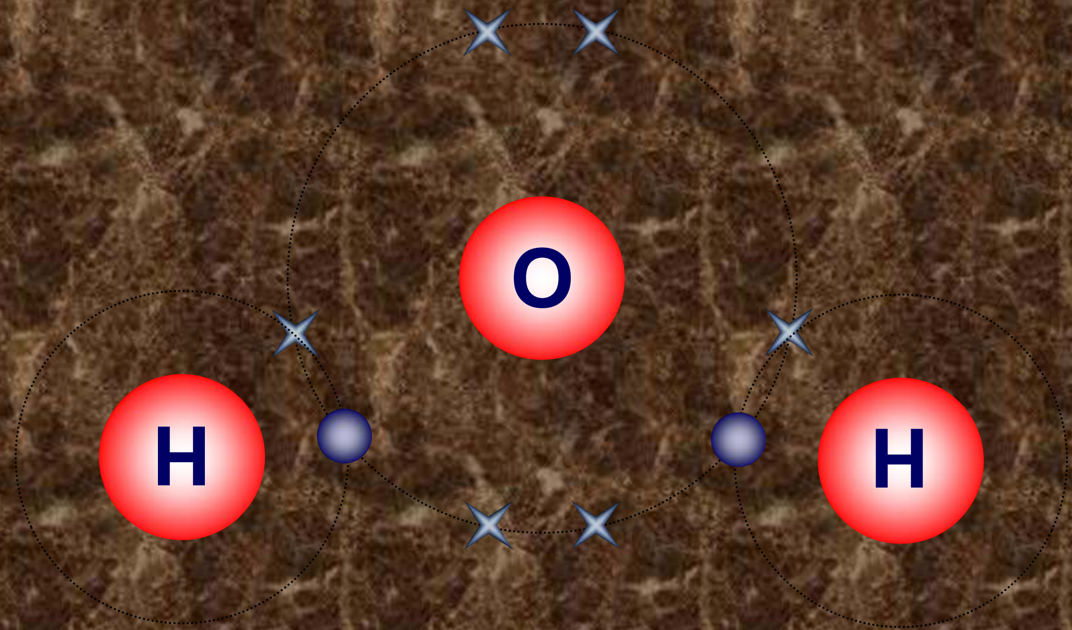


HCl or H–Cl

Covalent bonding in water

- Oxygen (2.6) needs 2 more electrons, but hydrogen (1) only needs 1 more. How can these two elements be covalently bonded?

The oxygen atom shares 1 electron with 1 hydrogen atom, and a second electron with another hydrogen atom.

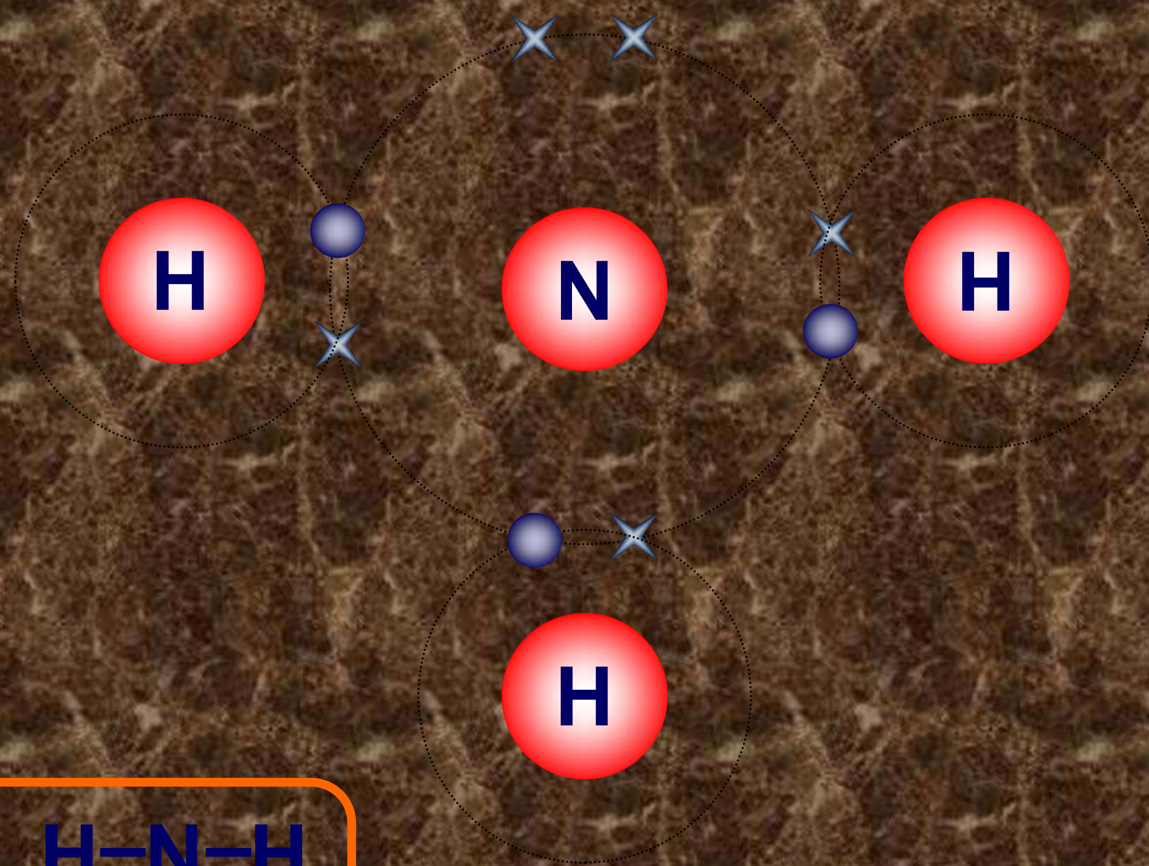


H_2O or H–O–H

Covalent bonding in ammonia

- How are nitrogen and hydrogen bonded in ammonia?

	N	H
Electron configuration	2.5	1
Electrons needed	3	1
Ratio of atoms	1	3

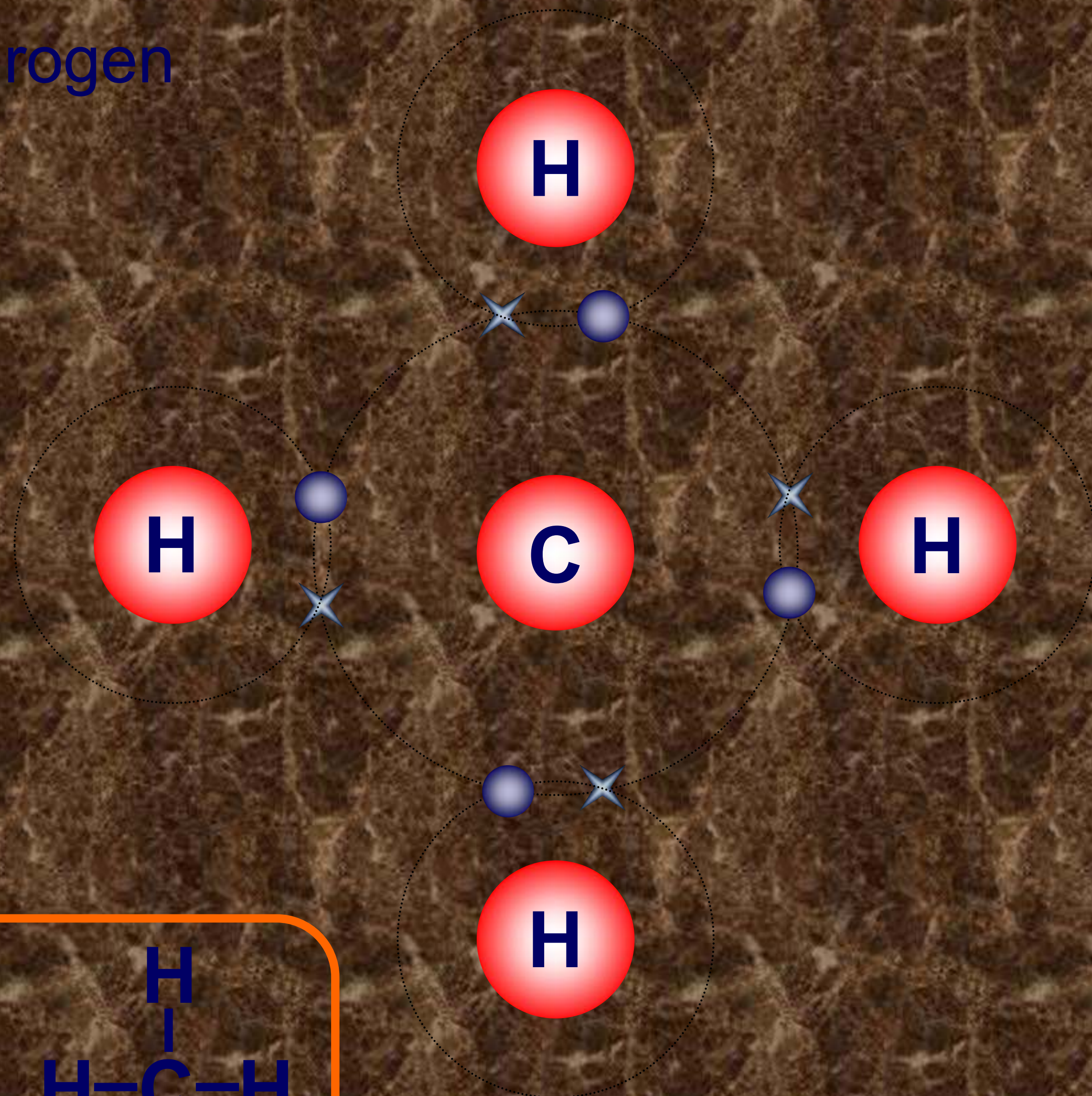


NH_3 or H–N–H with H bonded below N

Covalent bonding in methane

- How are carbon and hydrogen bonded in methane?

	C	H
Electron configuration	2.4	1
Electrons needed	4	1
Ratio of atoms	1	4



CH_4 or

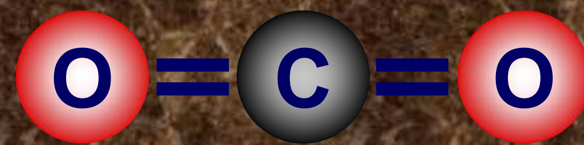
```
    H
    |
H — C — H
    |
    H
```

More covalent bonding diagrams

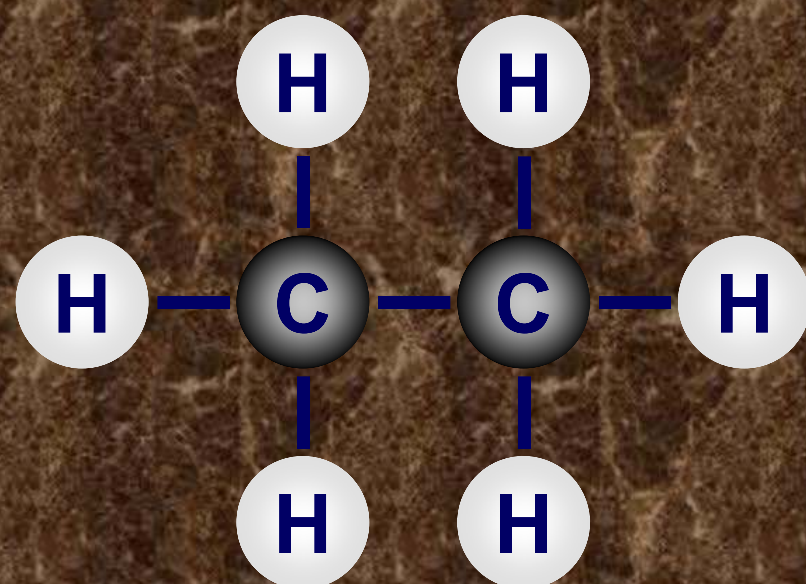
- Draw a line diagram to show the bonding in:

1. hydrogen sulfide

2. carbon dioxide



3. ethane (C_2H_6)



True or false?

Are these statements about covalent bonding true or false?

1. Atoms bond to half complete their outer shell.	
2. Non-metals rarely form covalent bonds.	
3. A covalent bond is a shared pair of electrons.	
4. Oxygen molecules contain a double bond.	
5. Sodium chloride contains covalent bonds.	
6. Covalent bonds only occur in compounds.	

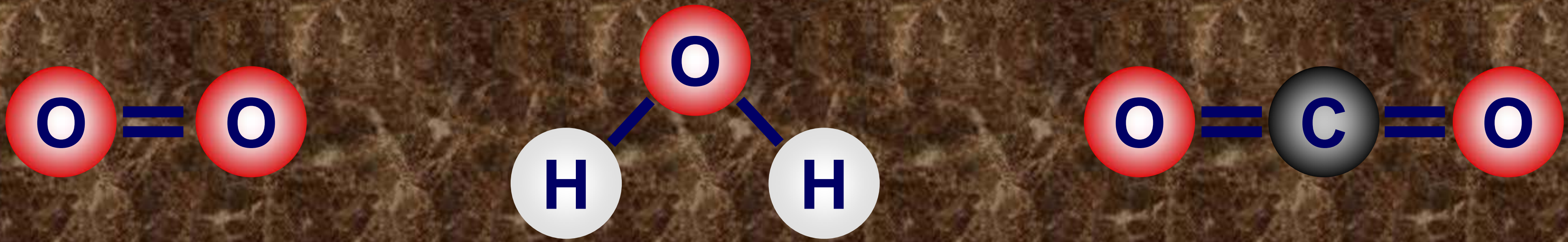
true false

Covalent structures

Simple covalent structures

- Atoms that join together by covalent bonding can form different types of covalent structure.

Oxygen, water and carbon dioxide are molecules. They have a **simple structure** because they only contain a few atoms.

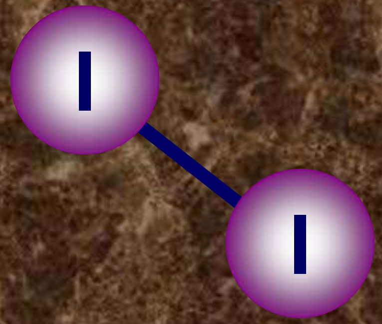


Most molecular substances are gas or liquid at room temperature. A few are solid and these are called **molecular solids**.

Molecular solids – iodine

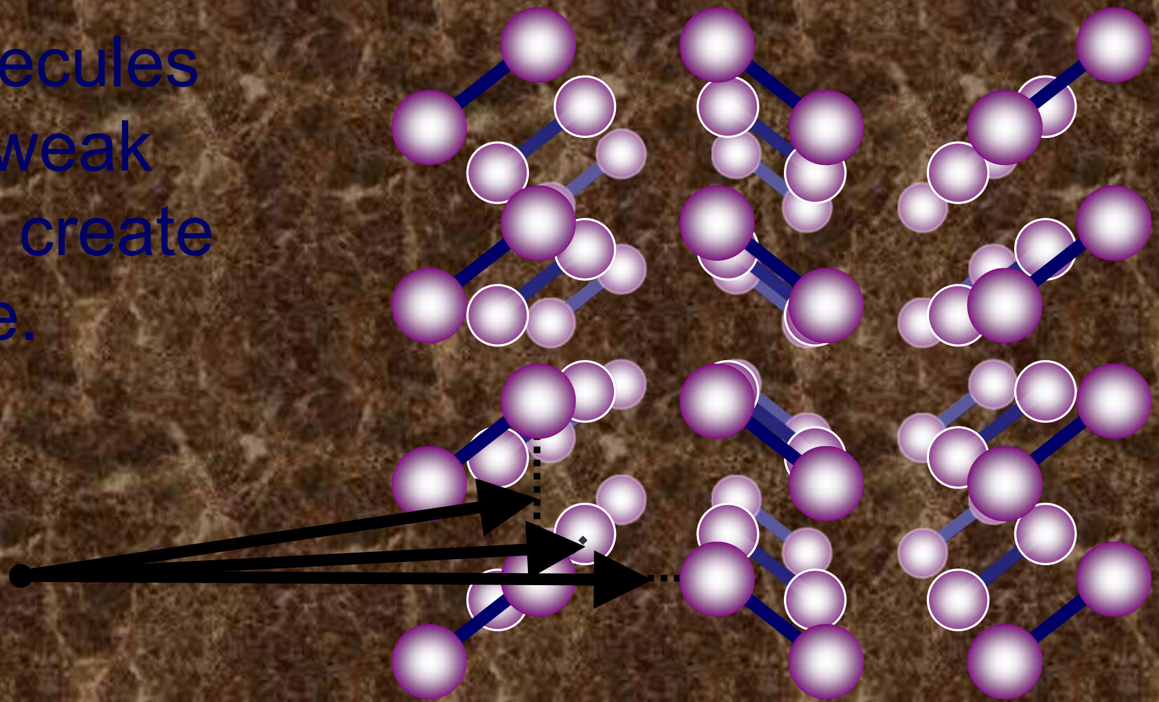
- Iodine is a molecular solid at room temperature.

Two iodine atoms form a single covalent bond to become an iodine molecule.



Millions of iodine molecules are held together by weak forces of attraction to create a 3D molecular lattice.

weak forces of attraction



Properties of molecular solids

- The weak forces of attraction between molecules in molecular solids only require a small amount of energy to be broken. This means that molecular solids:

  - have low melting and boiling points;
  - are usually soft and brittle – they shatter when hit.

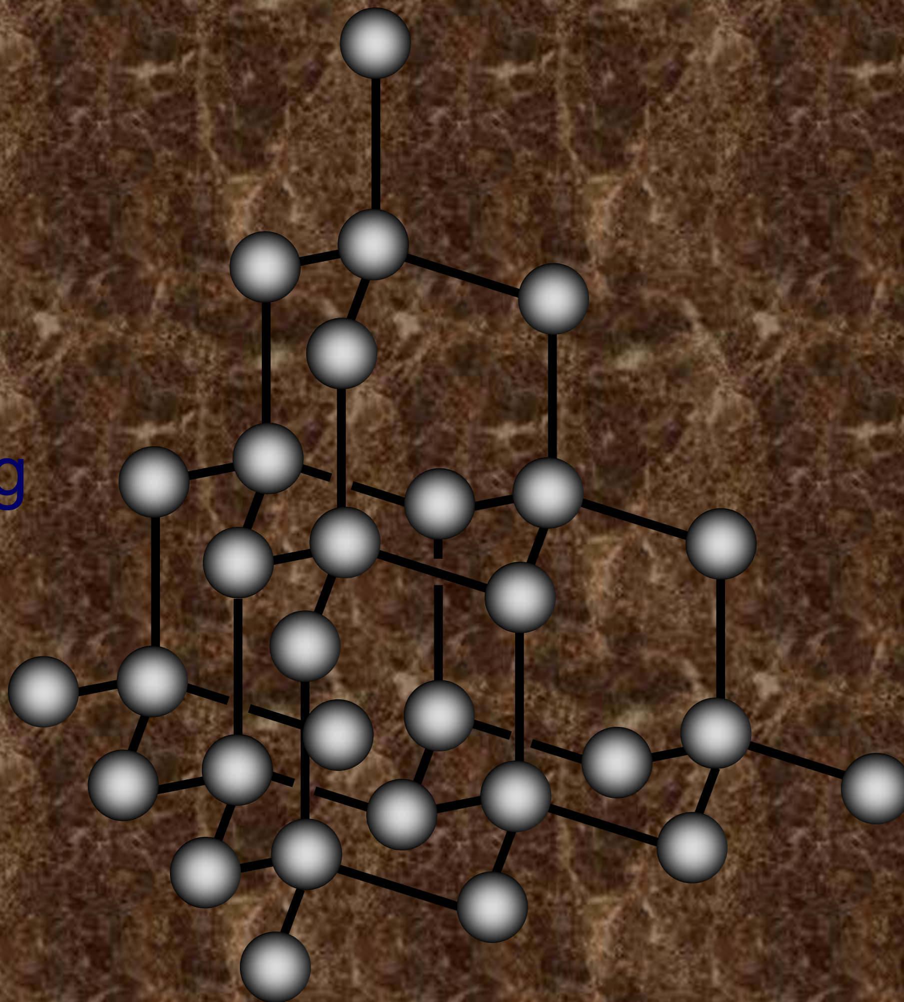
  In addition, molecular solids:

  - are usually insoluble in water but soluble in other solvents such as petrol;
  - cannot conduct electricity – there are no free electrons to carry an electrical charge.

Giant covalent structures

- In some substances, millions of atoms join together by covalent bonding. This produces **giant covalent structures**, not molecules.

All the bonds are covalent, which means that giant covalent structures have a very high melting and boiling point, and are usually hard.



Allotropes of carbon

- In the element carbon, atoms bond in different ways, creating different kinds of giant structures.

  Two of these structures are **diamond** and **graphite**. They are called **allotropes** of carbon.

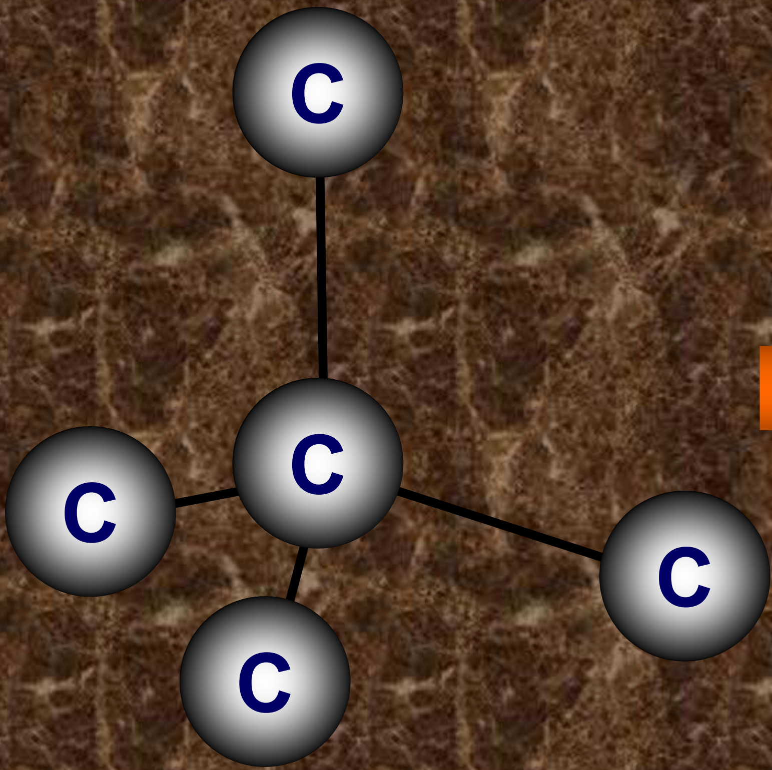
  Allotropes have the same chemical properties because they have the same number of electrons.

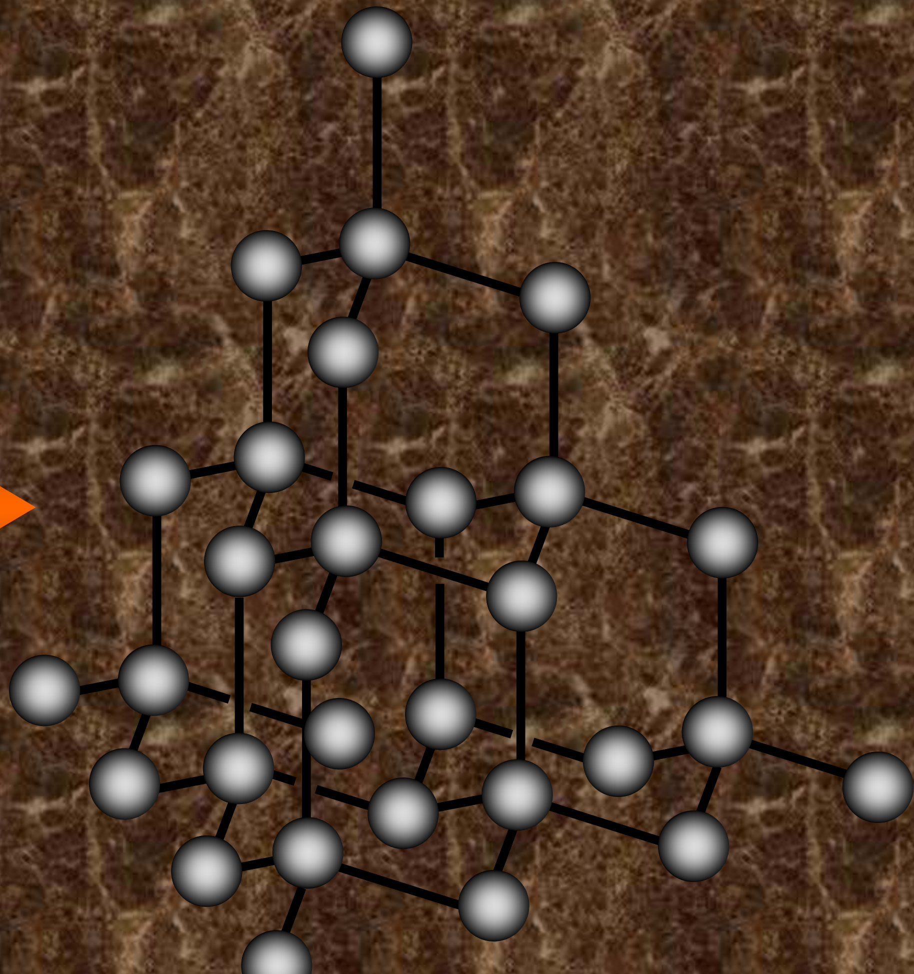
  However, they have different physical properties because the electrons are shared in different ways with other atoms.

The structure of diamond

- Diamond is a rare form of carbon in which each atom is covalently bonded to four others.

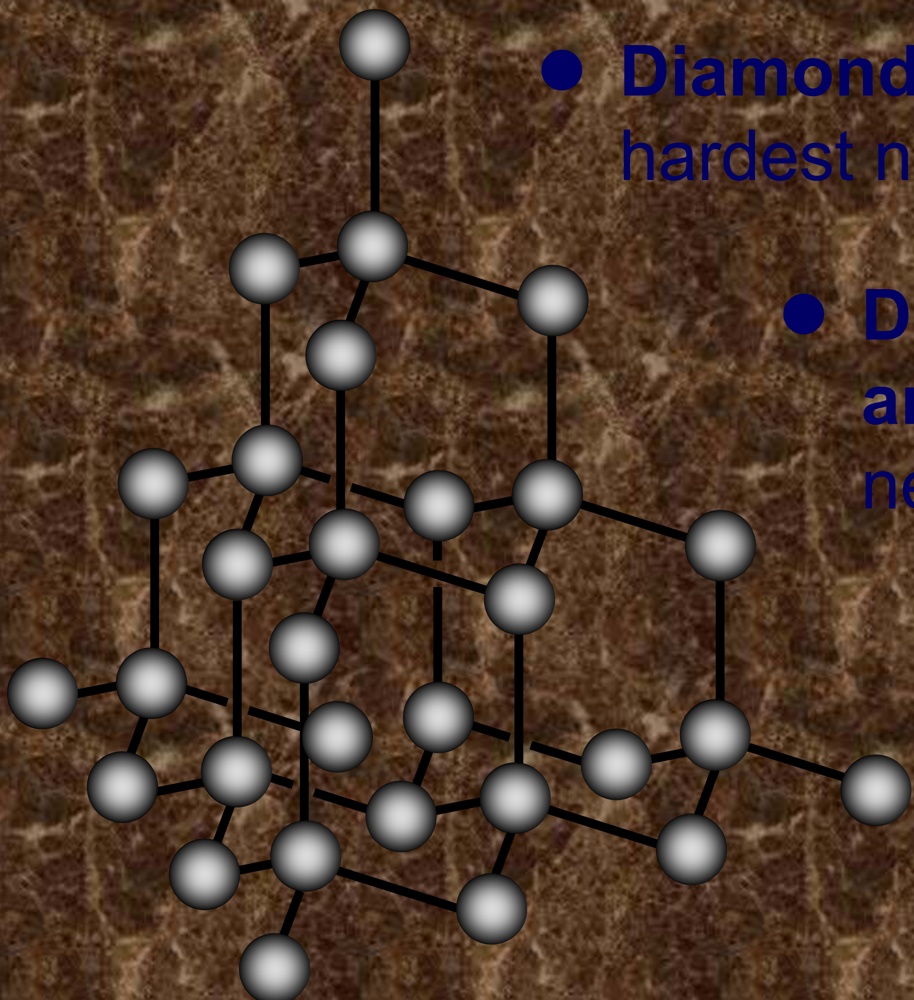
This pattern arrangement is repeated millions of times to create a giant lattice.





The properties of diamond

- All the electrons in the outer shell of the carbon atom (2.4) are used in covalent bonds. This affects diamond's properties.

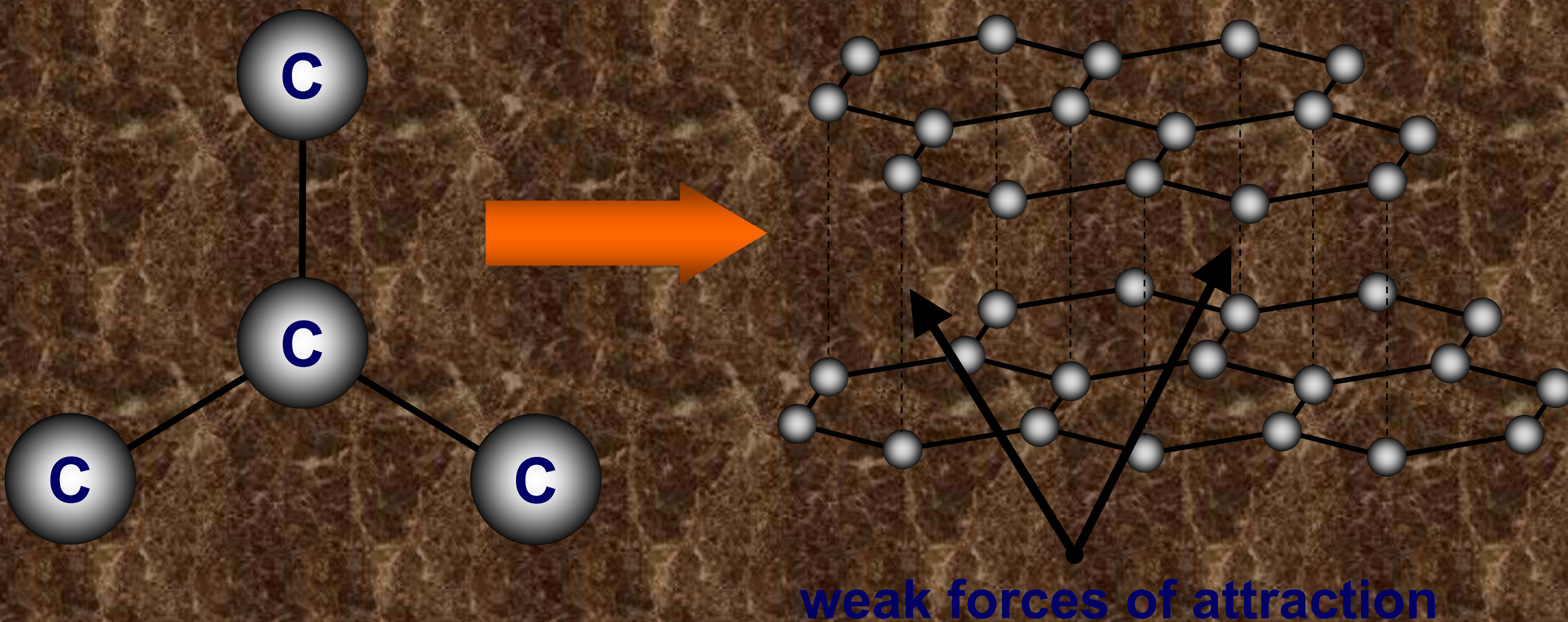


- **Diamond is very hard** – the hardest natural substance on Earth.
- **Diamond has a very high melting and boiling point** – a lot of energy is needed to break the covalent bonds.
- **Diamond cannot conduct electricity** – there are no free electrons or ions to carry a charge

The structure of graphite

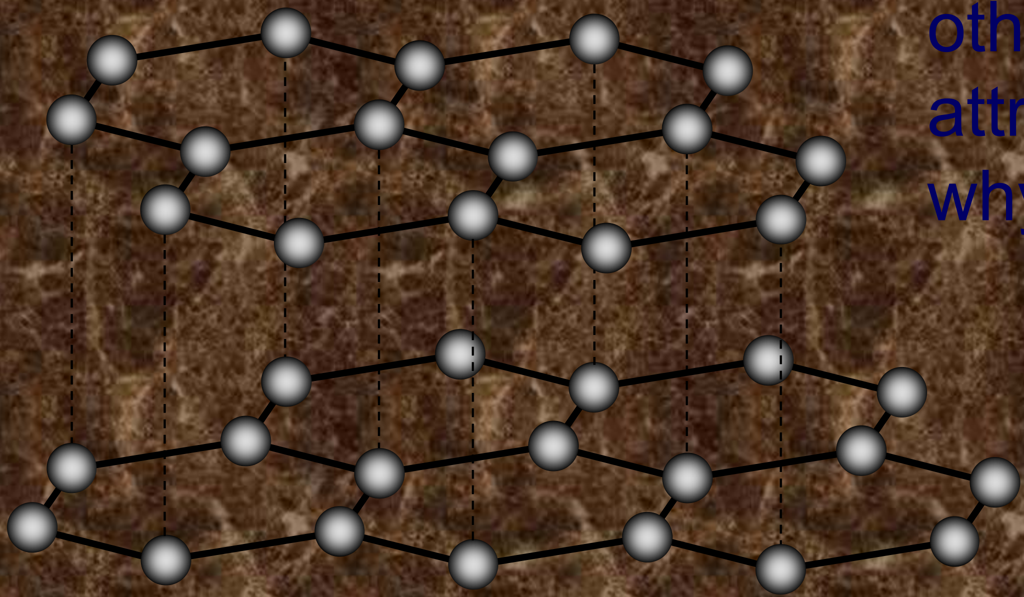
- Graphite is a much more common form of carbon. in which each atom is covalently bonded to three others.

This forms rings of six atoms, creating a giant structure containing many layers. These layers are held together by weak forces of attraction.



The properties of graphite

- Only three of the four electrons in the outer shell of the carbon atom (2.4) are used in covalent bonds. This affects graphite's properties.



- **Graphite is soft and slippery** – layers can easily slide over each other because the weak forces of attraction are easily broken. This is why graphite is used as a lubricant.

- **Graphite can conduct electricity** – the only non-metal to do. There is a free electron from each atom to carry a charge.

Allotropes and their properties

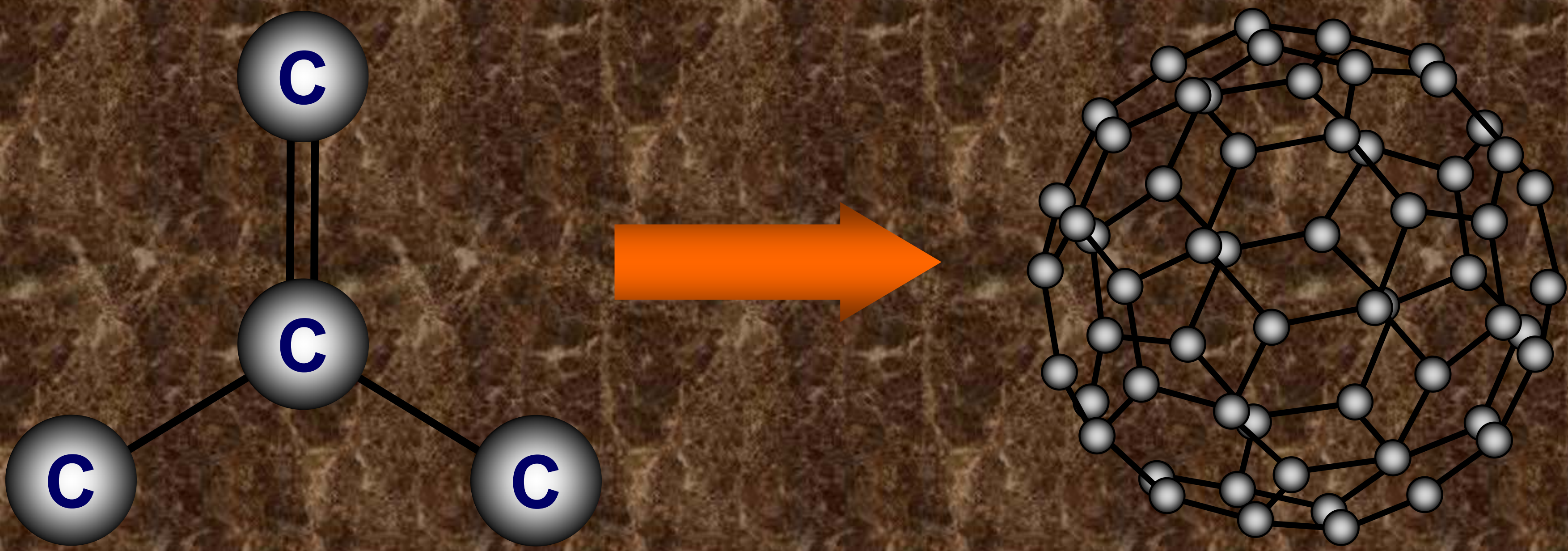
- How do the different properties of diamond and graphite depend on their structures?

Other allotropes of carbon

- Other allotropes of carbon have been discovered in the last 30 years. They are large but not really giant structures.

One allotrope is **buckminsterfullerene**. It contains 60 carbon atoms, each of which bonds with three others by forming two single bonds and one double bond.

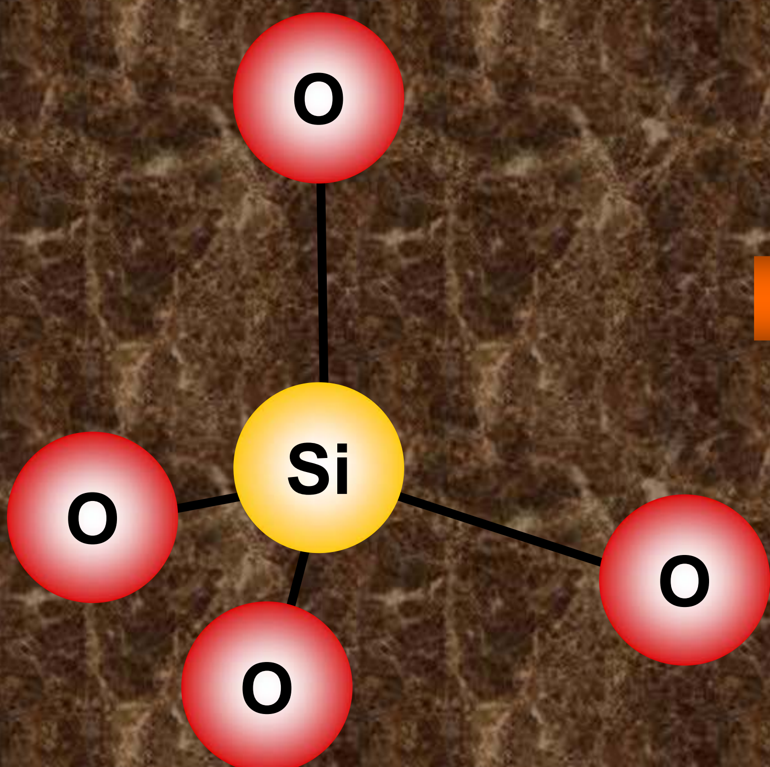
These atoms are arranged in 12 pentagons and 20 hexagons to form spheres, which are sometimes called 'bucky balls'.

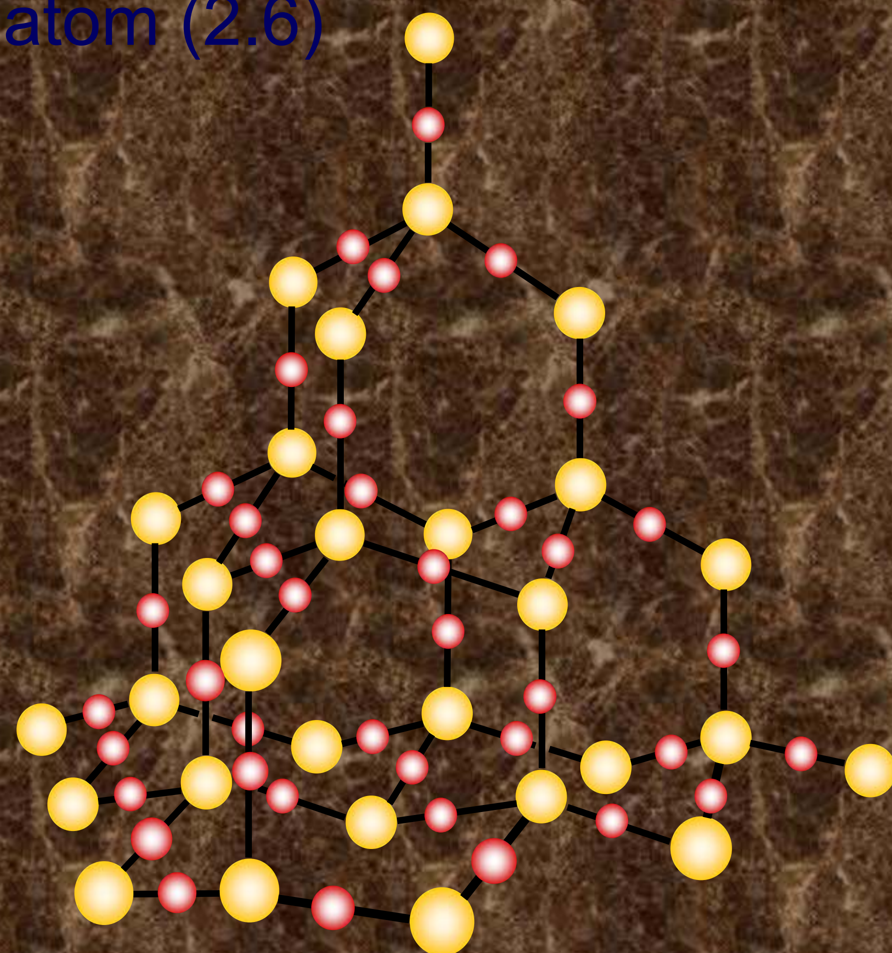


Sand

- Sand is an impure form of silicon dioxide (quartz). It has a giant covalent structure with certain similarities to diamond.

  Each silicon atom (2.8.4) is bonded to four oxygen atoms, and each oxygen atom (2.6) is bonded to two silicon atoms.

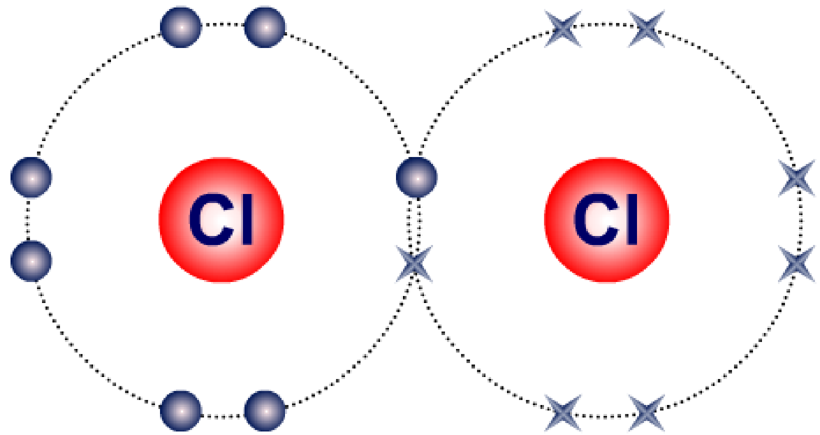




Bonding and structure

Which words match the substance?

chlorine



giant structure	double bond	single bond	triple bond	diatomic
compound	element	simple structure	molecule	allotrope

Summary activities

Glossary (part 1)

- **allotrope** – A structurally different form of an element with different physical properties.
- **covalent bond** – A strong bond between two atoms in which each atom shares one or more electrons with the other.
- **covalent compound** – A compound containing atoms joined by covalent bonds.
- **double bond** – A covalent bond in which each atom shares two of its electrons.
- **giant structure** – A structure containing millions of atoms or ions bonded together. The structure extends in three dimensions until all available atoms are used up.

Glossary (part 2)

- **molecule** – A simple structure containing two or more atoms covalently bonded together.
- **molecular solid** – A solid substance made up of molecules held together by weak forces of attraction, forming a lattice.
- **single bond** – A covalent bond in which each atom shares one of its electrons.
- **triple bond** – A covalent bond in which each atom shares three of its electrons.