Iron – a metal

Target level
This probe is designed for able students in the 14–16 age range who have been introduced to the properties of metals, and to the basic notion of metallic bonding, and for post-16 students.

Topics
Metallic structure and bonding; explaining properties using the particle model.

Rationale
Students often have considerable difficulty in using atomic/molecular-level models of matter to explain the properties of substances (see Chapter 6 of the Teachers' notes). It is also common for students to commence post-16 studies believing (a) that all materials have either covalent or ionic bonding, and (b) that ionic and metallic materials are molecular (see Chapter 8 of the Teachers' notes).

This exercise asks students to judge the veracity of twenty statements about one of the most familiar examples of a metal, iron.

During piloting, it was found that the items elicited student confusion between the properties of particles, and bulk properties. It was felt that the probe, and the feedback sheet, helped students clarify their ideas about the origins of the bulk properties of the metal. Teachers may be surprised at the number of students demonstrating the alternative conceptions targeted in this probe.

Instructions
It is worth reiterating to the students that the diagram shows just a small part of a slice through the lattice structure - and that the real structure is three-dimensional.

A blank answer sheet is provided offering the options 'true', 'false' and 'do not know' for each item. An alternative version of the answer sheet only includes the 'true' and 'false' options as some teachers prefer not to allow a 'do not know' option.

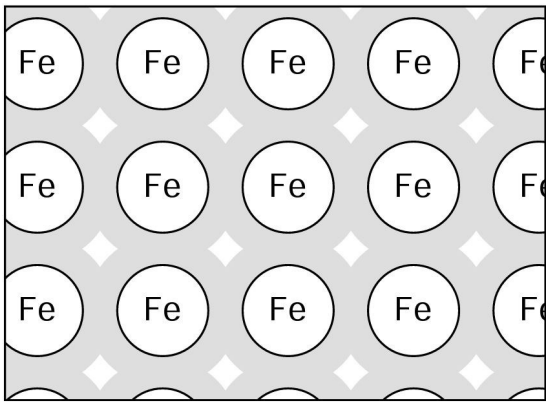
Resources
_ Student worksheets
– Iron – true or false?
– True or false? – response sheets (two versions)
– Iron – answers

Feedback for students
A suggested feedback sheet is provided for students (**Iron – answers**) and teachers may wish to issue this after students have tackled the probe.

Iron usually has a body centred cubic lattice (with coordination number 8). Teachers may wish to point out that many common metals have a slightly different structure - being close packed with a coordination number of 12.

Iron – answers

Below you will find listed the 20 statements you were asked to think about. Following each is a brief comment suggesting whether or not the statement is true, and why.

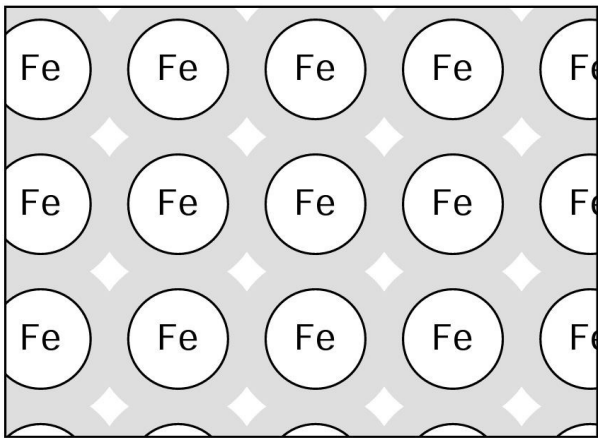


1. Iron has a type of bonding called metallic bonding. **TRUE**: iron is a metal, and all metals have a type of bonding called metallic bonding which is different from covalent and ionic bonding. In metallic bonding the outer shells of adjacent atoms overlap, and the outer shell electrons are free to move about through the lattice. The metal consists of metal cations and a balancing number of these 'free' electrons.
2. Iron atoms do not have a full outer shell of electrons, and this makes iron very reactive. **FALSE**: although an isolated iron atom has an electronic configuration of 2.8.14.2, the outer electrons are involved in the bonding in the metal. Iron is not very reactive, although it will slowly rust.
3. An iron atom is a silver-grey colour, and so iron metal is a silver-grey colour. **FALSE**: the colour of iron is a property of the arrangement of cations and electrons. A single atom of iron would not have a colour.
4. Iron can conduct electricity because some of the iron atoms can slip over their neighbours, and move through the solid. **FALSE**: the iron cations are normally fixed in their lattice positions. It is the electrons from the outer shells that are able to move about, allowing electrical current to flow through the metal.
5. Iron can be reshaped, without changing the shape of iron atoms. **TRUE**: metals can be worked into different shapes by hammering to force the cations to slip over each other. The cations change position, but not shape.
6. The reason iron rusts is that iron atoms will rust if exposed to damp air. **FALSE**: the rusting of iron is due to a chemical reaction between the iron and oxygen and water vapour in the air. During these reactions some of the iron cations and electrons become part of a new chemical compound (the rust), but the atoms themselves do not corrode.
7. In iron metal each atom is bonded to each of the other iron atoms surrounding it. **TRUE**: the iron atoms are packed together so that each iron cation is surrounded by eight others as if it is in the centre of a cube. The structure is held together by metallic bonding.
8. Iron conducts electricity because iron atoms are electrical conductors. **FALSE**: the metal conducts because some electrons are able to move through the metallic lattice structure. The individual atoms can not be considered to conduct. The outer electrons are only able to leave the cations because the outer electron shells overlap.

9. Iron is a solid because that is the natural state for metals. **FALSE**: the natural state depends on the temperature. Deep in the earth – where it is very hot – iron is a liquid. One metal called mercury is a liquid at room temperature.
10. A metal such as iron consists of positive metal ions, and negative electrons which move around the solid between the ions. **TRUE**: the iron structure contains iron cations surrounded by the fast moving electrons that would be in outer shells of separate iron atoms. (Sometimes this is called a 'sea of electrons'.)
11. An iron atom will reflect light, and so freshly polished iron shines. **FALSE**: polished metal will form a mirror because of the regular lattice of cations and the 'sea' of electrons. Individual iron atoms would not reflect light.
12. The reason that iron becomes a liquid when heated is because the bonds melt. **FALSE**: the metal melts when enough energy is provided to allow the cations to slip over each other. The bonds in the liquid metal are weaker than in a solid metal. If the liquid was heated until it boiled the bonds would break (but not 'melt').
13. Iron conducts electricity because it contains a 'sea' of electrons. **TRUE**: the electrons are able to move about, and will pass along the metal when it is connected to a battery.
14. The atoms in a metal such as iron are held together by ionic bonds. **FALSE**: the bonding in a metal is metallic bonding. This is different from ionic bonding as there are no anions (negative ions) present.
15. The reason iron conducts heat is because there is room between the atoms for hot air to move through the metal. **FALSE**: the iron cations are held close together by the metallic bonding, and there is no room for other atoms and molecules to get between them. Heat passes along the metal due to lattice vibrations and the movement of electrons.
16. The reason that iron is hard, is because iron atoms are hard. **FALSE**: hardness is a property of the metal due to the strong bonding holding the structure together. It is the arrangement of cations and free electrons which makes the metal hard.
17. In iron, there are molecules held together by magnetism. **FALSE**: there are no molecules in a metal - each cation is bonded to all those around it by the 'sea' of electrons, and those cations are bonded to others, and so on. Each cation in a metallic crystal is bonded (indirectly) to all the others.
18. If a metal such as iron is heated to a very high temperature it would become a gas. **TRUE**: if a solid metal is heated it will melt, and if heating is continued to a high enough temperature the liquid metal will boil.
19. Metals such as iron expand when heated because the atoms get bigger. **FALSE**: when the metal is heated the cations vibrate more, and move a little further apart.
20. Chemical bonds are needed to hold the atoms together in a metal such as iron, even though all of the atoms are of the same type. **TRUE**: the atoms would not remain joined together if there was no bonding between them. This is true for all solids whether the atoms are of one type (in an element) or several (in a compound).

Iron – true or false?

The statements below refer to the diagram of the structure of iron. The diagram shows part of a slice through the three dimensional structure.



Please read each statement carefully, and decide whether it is correct or not.

1. Iron has a type of bonding called metallic bonding.
2. Iron atoms do not have a full outer shell of electrons, and this makes iron very reactive.
3. An iron atom is a silver-grey colour, and so iron metal is a silver-grey colour.
4. Iron can conduct electricity because some of the iron atoms can slip over their neighbours, and move through the solid.
5. Iron can be reshaped, without changing the shape of iron atoms.
6. The reason iron rusts is that iron atoms will rust if exposed to damp air.
7. In iron metal each atom is bonded to each of the other iron atoms surrounding it.
8. Iron conducts electricity because iron atoms are electrical conductors.
9. Iron is a solid because that is the natural state for metals.
10. A metal such as iron consists of positive metal ions, and negative electrons which move around the solid between the ions.
11. An iron atom will reflect light, and so freshly polished iron shines.
12. The reason that iron becomes a liquid when heated is because the bonds melt.
13. Iron conducts electricity because it contains a ‘sea’ of electrons.
14. The atoms in a metal such as iron are held together by ionic bonds.
15. The reason iron conducts heat is because there is room between the atoms for hot air to move through the metal.
16. The reason that iron is hard is because iron atoms are hard.
17. In iron there are molecules held together by magnetism.
18. If a metal such as iron is heated to a very high temperature it would become a gas.
19. Metals such as iron expand when heated because the atoms get bigger.
20. Chemical bonds are needed to hold the atoms together in a metal such as iron, even though all of the atoms are of the same type.

True or false? – response sheet

1.	True	False	1.
2.	True	False	2.
3.	True	False	3.
4.	True	False	4.
5.	True	False	5.
6.	True	False	6.
7.	True	False	7.
8.	True	False	8.
9.	True	False	9.
10.	True	False	10.
11.	True	False	11.
12.	True	False	12.
13.	True	False	13.
14.	True	False	14.
15.	True	False	15.
16.	True	False	16.
17.	True	False	17.
18.	True	False	18.
19.	True	False	19.
20.	True	False	20.

True or false? – response sheet

1.	True	Do not know	False	1.
2.	True	Do not know	False	2.
3.	True	Do not know	False	3.
4.	True	Do not know	False	4.
5.	True	Do not know	False	5.
6.	True	Do not know	False	6.
7.	True	Do not know	False	7.
8.	True	Do not know	False	8.
9.	True	Do not know	False	9.
10.	True	Do not know	False	10.
11.	True	Do not know	False	11.
12.	True	Do not know	False	12.
13.	True	Do not know	False	13.
14.	True	Do not know	False	14.
15.	True	Do not know	False	15.
16.	True	Do not know	False	16.
17.	True	Do not know	False	17.
18.	True	Do not know	False	18.
19.	True	Do not know	False	19.
20.	True	Do not know	False	20.