

14–16 years

Bonding models



Learning objectives

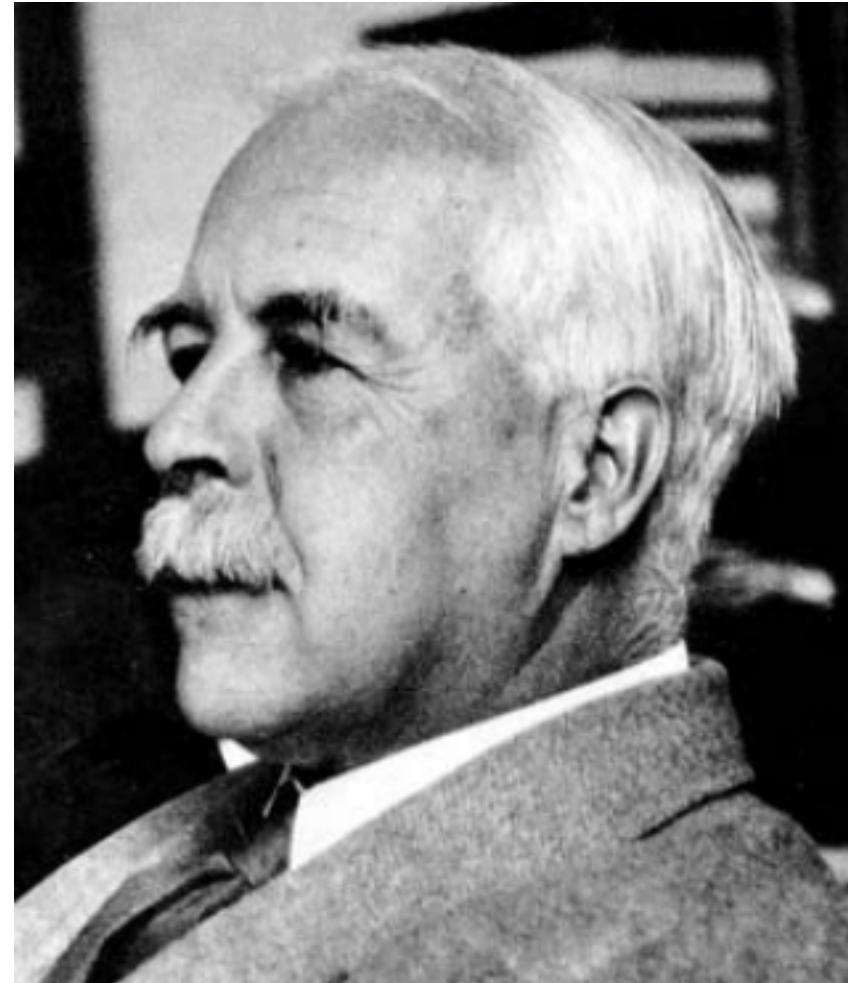
1. Model elements and compounds using an alternative representation of electron configuration.
2. Compare this alternative model with the dot and cross model of bonding.
3. Evaluate this alternative model for electron configuration and bonding.



Lewis structures

The person who is largely credited with developing the 'dot and cross' model of bonding was an American called Gilbert Newton Lewis (1875–1946).

Dot and cross representations are also called Lewis structures, particularly in America.



Gilbert Newton Lewis

Developing bonding models

Lewis's ideas developed over a long period of time, based on the observation that the periodicity of the properties of the elements seemed linked to the number eight.

If you arrange the elements in order of increasing atomic number, the properties of the elements fall into a repeating pattern every eight elements (with some exceptions!).

It follows from the work of Mendeleev on the periodic table and Newland's 'Law of Octaves'.

Newland's Law of Octaves

He	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca				

H1

Li3

Be4

Na11

Mg12

K19

Ca20

Rb37

Sr38

Cs55

Ba56

Fr87

88

Periodic Table

The Royal Society of Chemistry's interactive periodic table features history, alchemy, podcasts, videos, and data trends across the periodic table. Click the tabs at the top to explore each section. Use the buttons above to change your view of the periodic table and view Murray Robertson's stunning Visual Elements artwork. Click each element to read detailed information.

B5

C6

N7

O8

F9

Ne10

Al13

Si14

P15

S16

Cl17

Ar18

Ga31

Ge32

As33

Se34

Br35

Kr36

In49

Sn50

Sb51

Te52

I53

Xe54

Tl81

Pb82

Bi83

Po84

At85

Rn86

Nh113

Fl114

Mc115

Lv116

Ts117

Og118

Ce58

Pr59

Nd60

Pm61

Sm62

Eu63

Gd64

Tb65

Dy66

Ho67

Er68

Tm69

Yb70

Lu71

Th90

Pa91

U92

Np93

Pu94

Am95

Cm96

Bk97

Cf98

Es99

Fm100

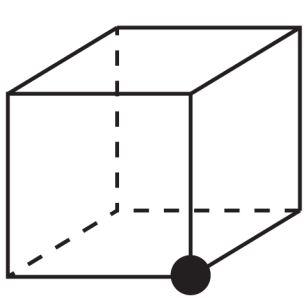
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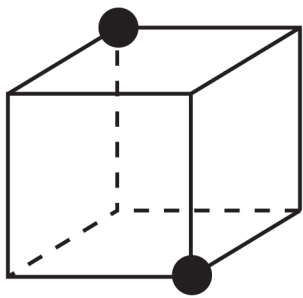
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How Lewis represented the structure of atoms

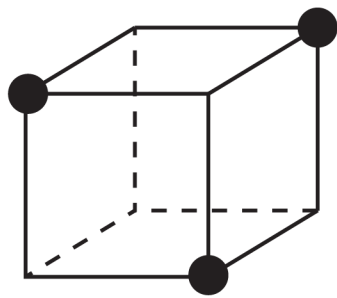
He initially represented the electron shells as cubes rather than the circles we use in the modern dot and cross model.



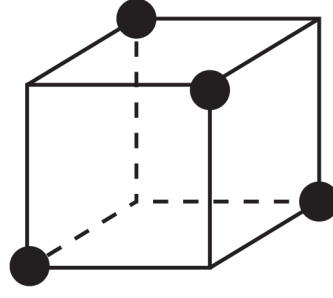
Li



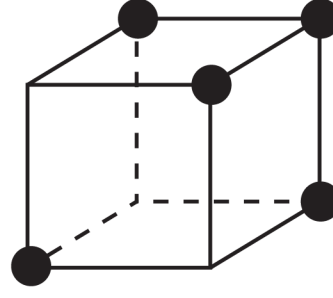
Mg



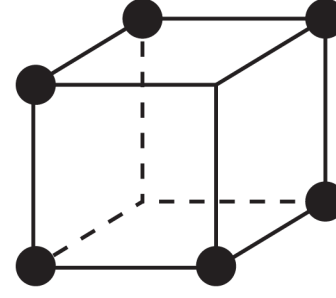
B



C



N




O

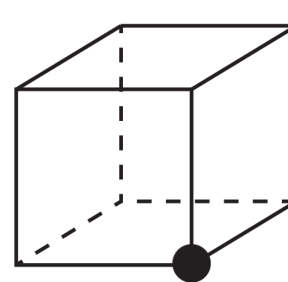
Lewis' model of electron shells

His ideas can be expressed as follows:

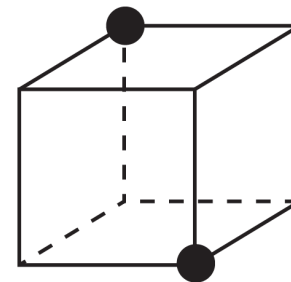
- The electrons in an atom are arranged in concentric cubes.
- A neutral atom of each element contains one more electron than a neutral atom of the next smallest element in the period.
- The cube of eight electrons is reached in the atoms of the noble gases and this cube becomes, in some sense, the core about which the larger cube of electrons of the next period is built. (Lewis believed that helium had eight electrons).
- The electrons of an outer, incomplete cube may be given to another atom, as in Mg^{2+} . Or enough electrons may be taken from other atoms to complete the cube, as in Cl^- , thus accounting for positive and negative ions.

Questions

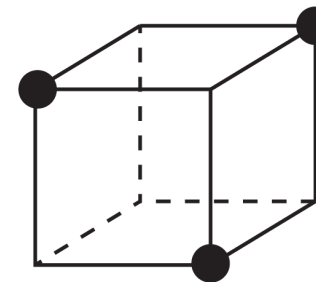
1. Can you suggest reasons why Lewis was attracted by the idea of the electrons occupying the corners of a cube?

2. Draw the electronic structure of neon using Lewis's ideas.
3. Draw the electronic structure of a sodium ion and a chloride ion.



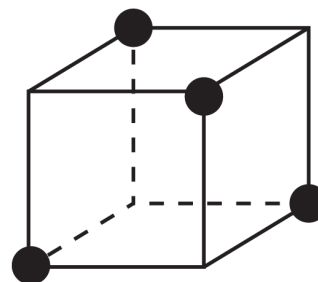
Li



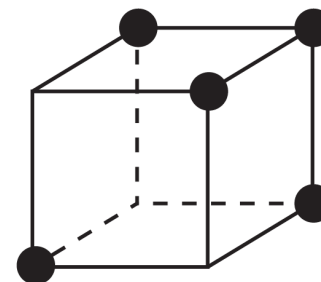
Mg



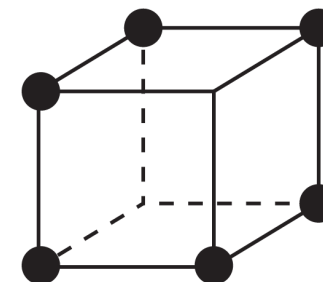
B



C



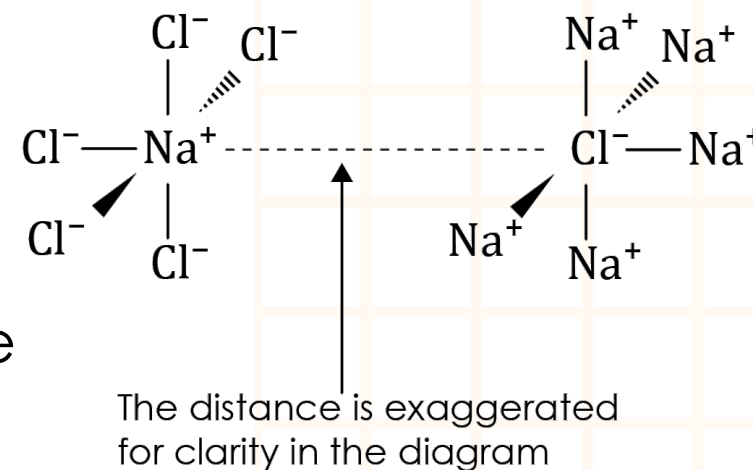
N



O

Questions

Oppositely charged ions attract each other. This attraction gives rise to ionic bonding. The ions group together in a vast three-dimensional array called a giant lattice. In the lattice of sodium chloride, each ion has six nearest neighbours of the oppositely charged ion. Sodium chloride is said to have a coordination number of six.



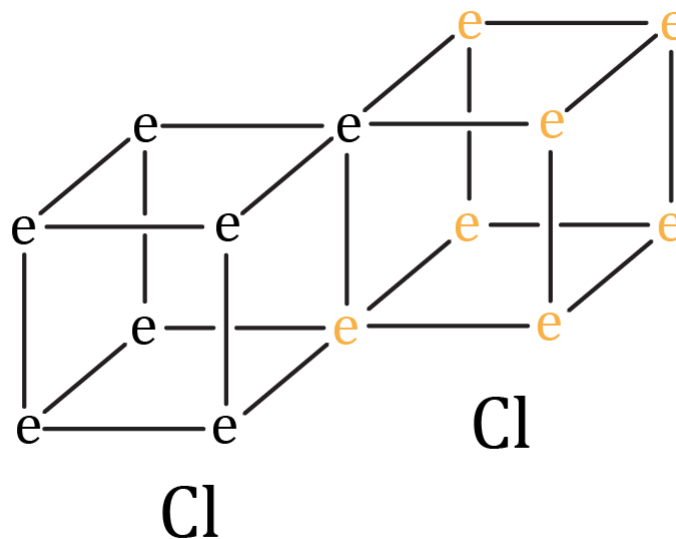
4. Explain how Lewis's cube model would account for the coordination number of sodium chloride.

Hint: can you find some connection between the shape of cubes and six?



Questions

5. Lewis could account for covalent bonds as the sharing of electrons. The diagram below shows the structure of Cl_2 . Draw similar diagrams for OF_2 and O_2 .



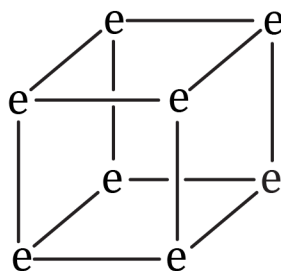
6. Is it possible to draw a structure similar to the one above showing a triple bond, as in the molecule N_2 ?

Discussion of answers

1. Can you suggest reasons why Lewis was attracted by the idea of the electrons occupying the corners of a cube?
 - Cubes have eight corners which fit nicely with the idea of having eight electrons in a 'shell'.
 - Cubes could stack easily together like crates in a warehouse.
 - Perhaps Lewis was influenced by the visible shape of crystals and imagined the atoms as tiny versions of these.

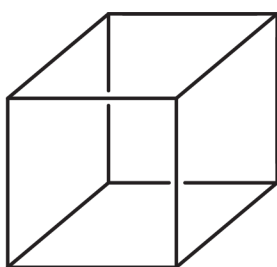
Discussion of answers

2. Draw the electronic structure of neon using Lewis's ideas.

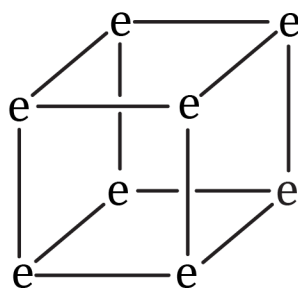


Ne

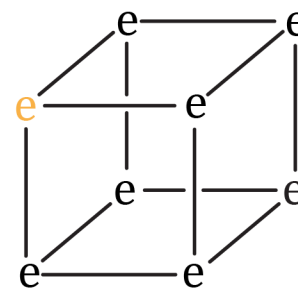
3. Draw the electronic structure of a sodium ion and a chloride ion.



or



Na⁺

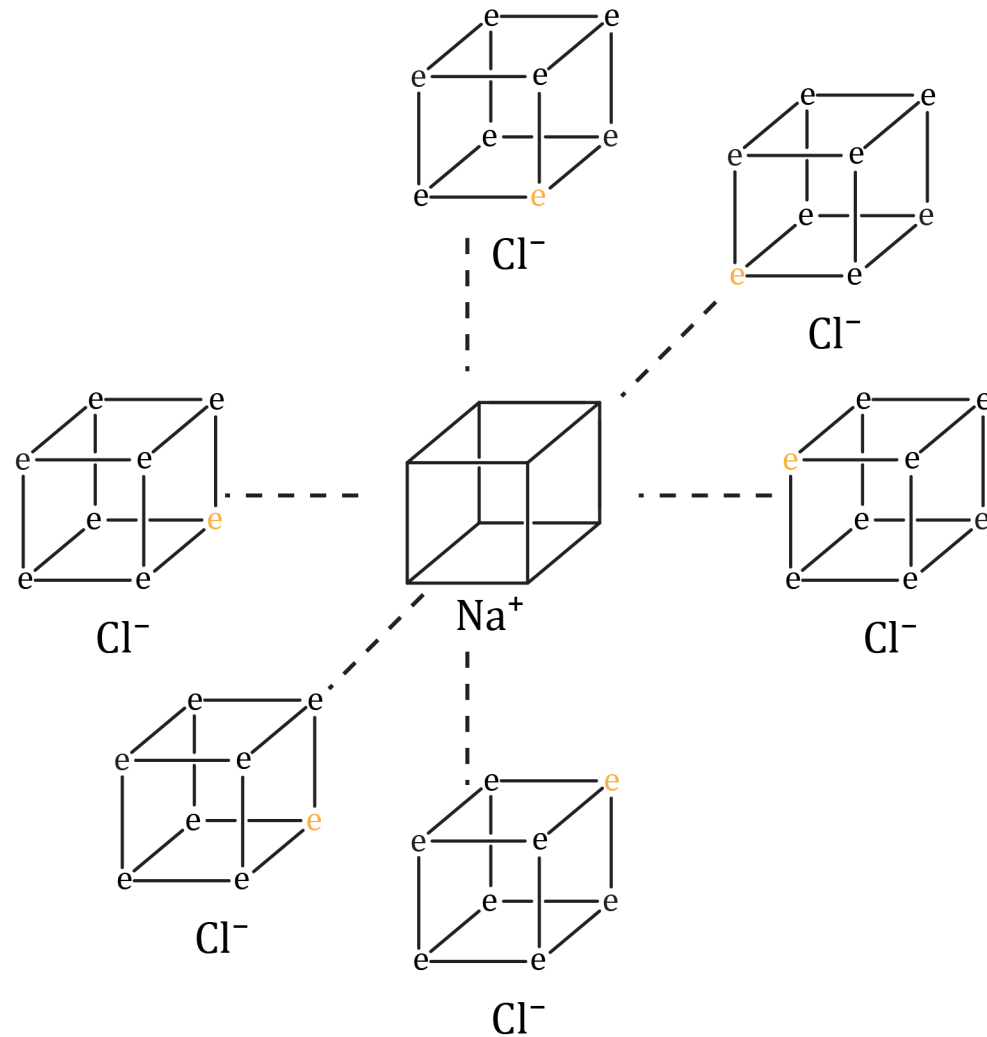


Cl⁻

Discussion of answers

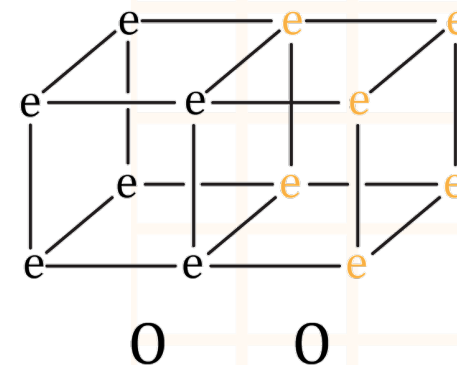
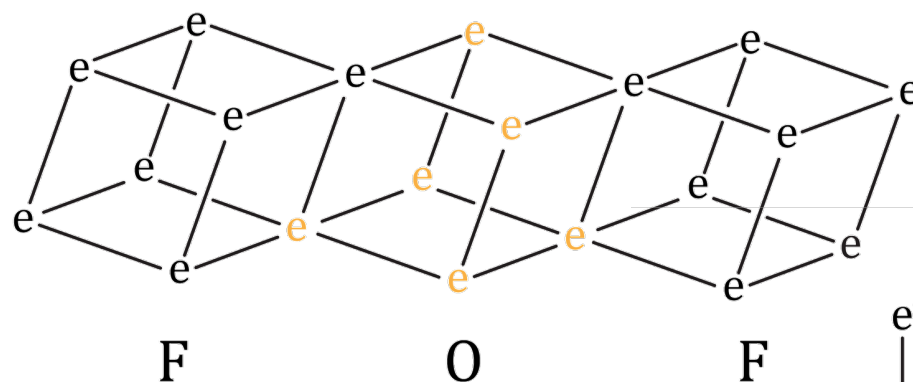
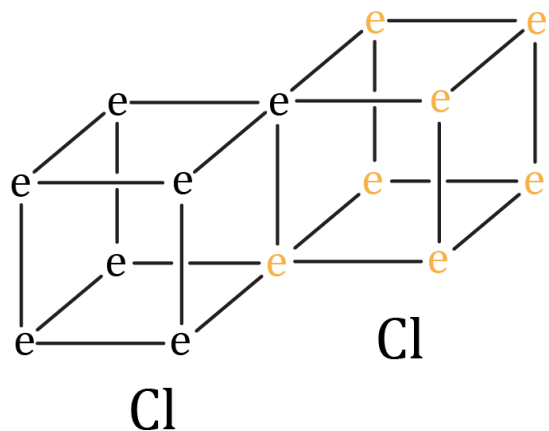
4. Explain how Lewis's cube model would account for the coordination number of the sodium chloride.

Each cube has six faces so could have six oppositely charged ions all equidistant alongside each face.



Discussion of answers

5. Lewis could account for covalent bonds as the sharing of electrons. The diagram below shows the structure of Cl_2 . Draw similar diagrams for OF_2 and O_2 .



6. Is it possible to draw a structure similar to the one above showing a triple bond as in the molecule N_2 ?

No, the most electrons that two atoms could share would be two each as the cubes touch faces.

Modelling activity

Using two colours of modelling clay and cocktail sticks, build models of:

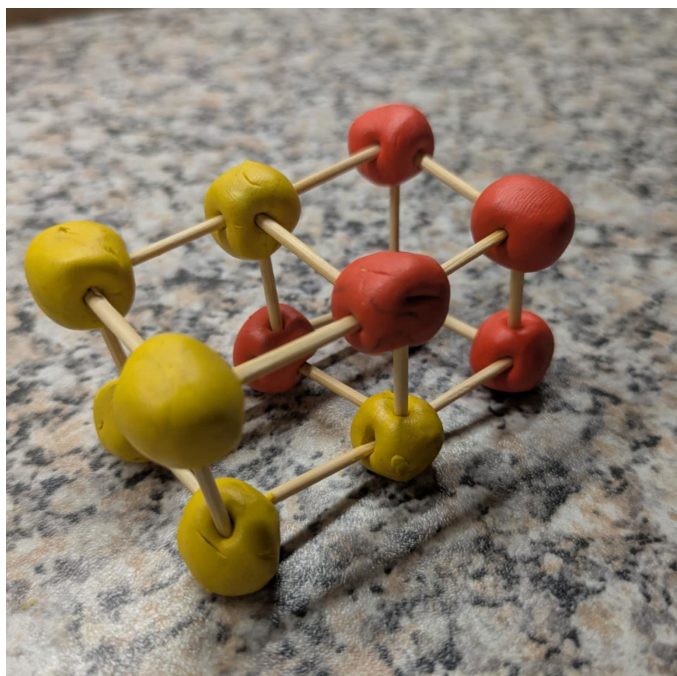
- Oxygen, O_2
- Carbon tetrachloride, CCl_4 .

There are two ways of arranging the chlorine atoms in carbon tetrachloride, CCl_4 - which do you think is best?



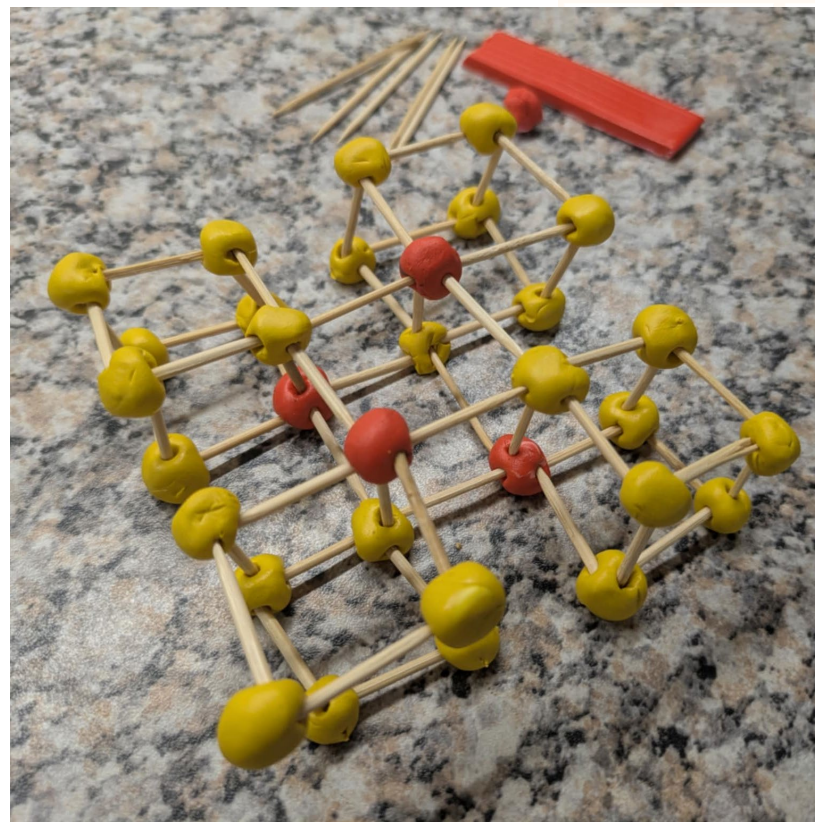
Modelling activity example answers

- Using two colours of plasticine and cocktail sticks, build models of O_2 and CCl_4 .



O_2

- = electrons from the outer shell of first oxygen atom.
- = electrons from the outer shell of second oxygen atom.

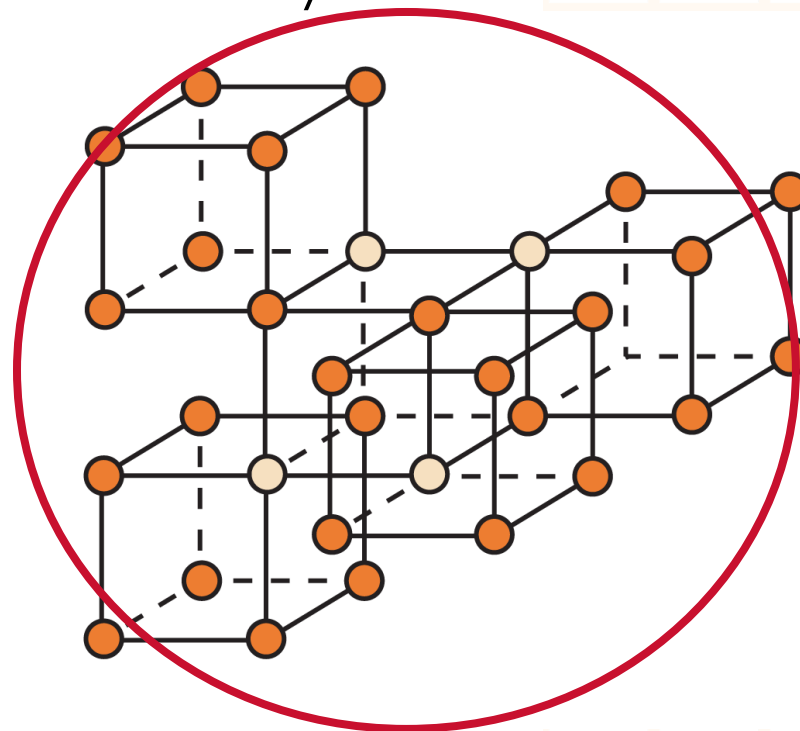
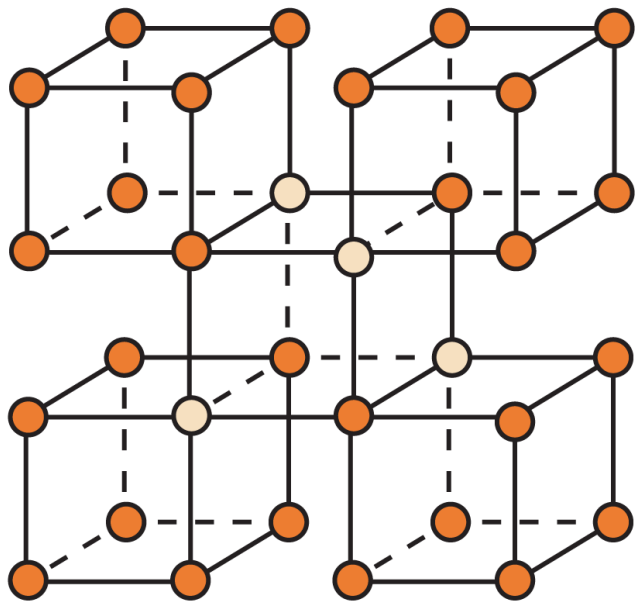


CCl_4

- = electrons from the outer shell of the carbon atom.
- = electrons from the outer shells of the chlorine atoms.

Modelling activity example answers

- There are two ways of arranging CCl_4 - which do you think is best?

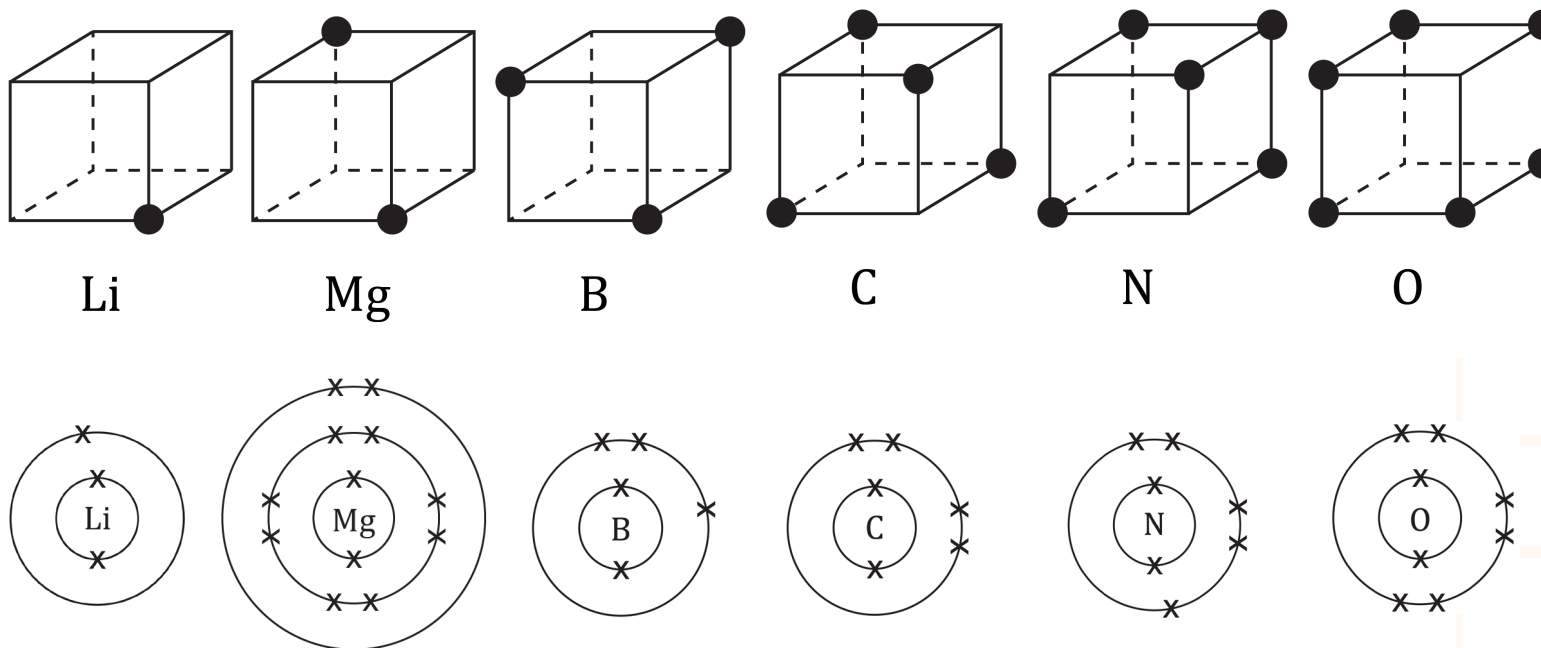


The preferred arrangement for CCl_4 is the one where the atoms are not all in the same plane as this allows the chlorine atoms more space. The CCl_4 molecule is really three dimensional not flat.

Discussion activity



- Compare the advantages and disadvantages of the cubic model with the circular dot and cross model.



- Why do you think Lewis abandoned cubes for representing atoms?

Suggested answers

Advantages of the Lewis cube model	Disadvantages of the Lewis cube model
<ul style="list-style-type: none">• Highlights that atoms and molecules are three dimensional, not two dimensional.• Easy to show a double bond.• Gives a rationale for eight electrons in the outer shell.	<ul style="list-style-type: none">• Does not show that electrons go in pairs.• Very hard to draw complex molecules.• Problem with the first period, hydrogen and helium, which only have two electrons in the outer shell.• Atoms lower down in the periodic table can have more than eight electrons in their outer shell – so you need to abandon the cube for a polyhedron with more corners.

Why do you think Lewis abandoned cubes for representing atoms?

Probably all of the points listed above contributed but importantly the cubes are too hard to draw in complex molecules. Atoms are certainly not cuboid in shape, but neither are they circular, or even truly spherical.



Research activity

Find out:

- What model of the atom was used before Lewis.
- What role Lewis took in the famous Manhattan project to produce the first nuclear bomb.

Margaret Melhase

Margaret was a chemistry undergraduate student in 1941. She also went on to work on the Manhattan project.

- What discovery did Margaret make while she was a student and why was it important?
- What barriers did Margaret face pursuing a career in chemistry? How is this different for women in chemistry today?



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Margaret Melhase