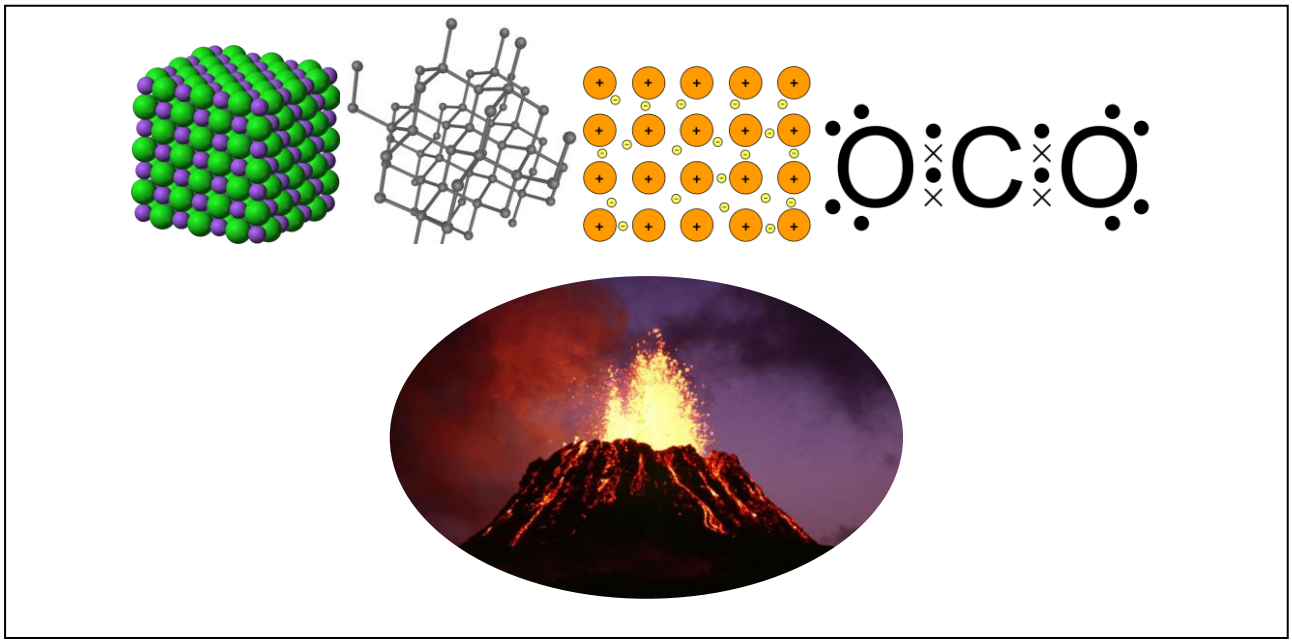
Compounds found in Magma: Structure and Bonding

Suitable for UK KS4 or ages 14-16

Notes for teachers

At a glance

The following resource uses volcanic activity as a context for engaging students with questions about bonding and structure. Students are asked a range of questions on each of the types of bonding introduced at GCSE (ionic, simple covalent, giant covalent and metallic) and so this resource is perhaps best suited to a review lesson.



Learning Outcomes

- Review understanding of structure and bonding
- Students practice their explanations of properties based on the structure of compounds.

Each student will need

- A copy of the student worksheet

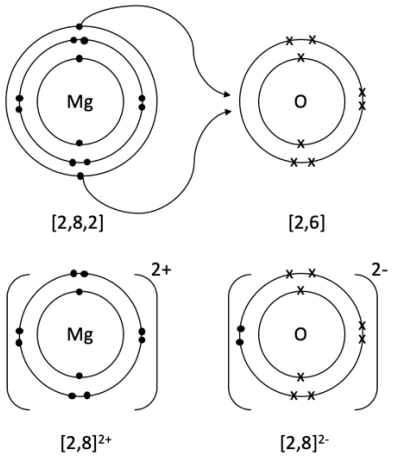
Possible Lesson Activities

1. **Starter activity**
    - Show the Oxford Sparks video 'Using your science to understand volcanic eruptions' (see web links) outlining a PhD student's research into volcanoes.
        - Highlight that understanding of the formation and structure of the compounds formed from lava allow Earth scientists to better predict the activity of volcanoes.

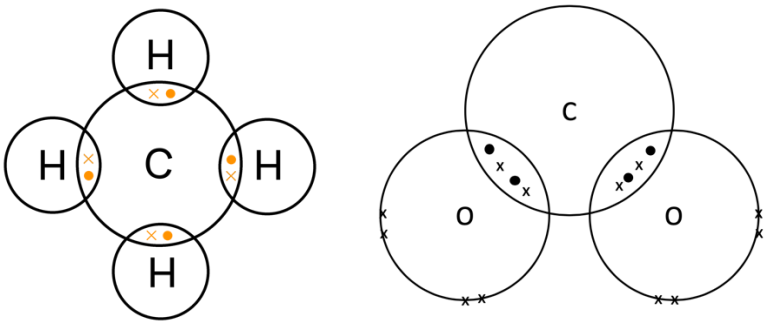
2. **Main activity: Structure and bonding questions**
    - Hand out student worksheet
    - Circulate to help and engage students with task
3. **Main activity: Structure and bonding answers**
    - *Q1 - Which of the above is not a compound? Explain why.*
        - *A – Diamond is not a compound because it only contains one type of atom (comprised of a single element (carbon)).*
    - *Q2 - By using a periodic table and by looking at the chemical composition of each of the above, give the type of bonding responsible for each.*
        - *A -*

Compound / Element	Type of Bonding
SiO_2	*Giant covalent/molecular*
CH_4	*Simple covalent/molecular*
Diamond (C)	*Giant covalent/molecular*
Fe_2O_3	*Ionic*
CO_2	*Simple covalent/molecular*
Fe_3O_4	*Ionic*
MgO	*Ionic*

    - *Q3 - Which of the above will have lattice structures?*
        - *A - SiO_2, Diamond (C), Fe_2O_3, Fe_3O_4 & MgO*
    - *Q4 - Ionic bonding involves the transfer of electrons. Explain why ionic bonding can only occur between a metal and a non-metal?*
        - *A – This is the only combination that suits electron transfer. Metals tend to lose electrons when they bond while non-metals tend to gain electrons when they bond.*
    - *Q5 - Using a dot and cross diagram, show the transfer of electrons in the formation of MgO.*
        - *A –*



- *Q6 - Ionic bonding results in the formation of ions. How do ions differ from atoms?*
  - *A – Atoms are neutral. Ions are charged due to the gain or loss of electrons*
- *Q7 - What is the name of the force that holds oppositely charged ions together?*
  - *A – Electrostatic forces of attraction*
- *Q8a - Suggest what oxidation state(s) or ion(s) iron is in when it forms Fe_2O_3 (hint – the compound must be neutral overall)*
  - *A – Fe^{3+}.*
- *Q8b - Suggest what oxidation state(s) or ion(s) iron is in when it forms Fe_3O_4 (hint – the compound must be neutral overall)*
  - *A – Two of the iron ions are Fe^{3+} and one of the iron ions is Fe^{2+}.*
- *Q9 - Some of the above compounds are held together by covalent bonds. What is a covalent bond?*
  - *A – A covalent bond is the electrostatic attraction between a negatively charged shared pair of electrons and the positive nuclei of the bonded atoms.*
- *Q10 - Draw a dot and cross diagram for a given simple covalent molecule.*
  - *A –*



- *Q11 - Some of the above will conduct. State which and under which conditions. For each, state why it will conduct?*
  - *A –*

Compound	Conduct? ✓or ✗	State(s) it will conduct?	Explanation: *What charged particles are free to move and carry a charge?*
SiO_2	✗		*There are no free moving charged particles*
CH_4	✗		*There are no free moving charged particles*

Diamond (C)	✗		*There are no free moving charged particles*
Fe_2O_3	✓	*Liquid or Aqueous*	*When liquid or aqueous the lattice structure is broken and the ions are free to move. As ions are charged, their movement generates a current.*
CO_2	✗		*There are no free moving charged particles*
Fe_3O_2	✓	*Liquid or Aqueous*	*When liquid or aqueous the lattice structure is broken and the ions are free to move. As ions are charged, their movement generates a current.*
MgO	✓	*Liquid or Aqueous*	*When liquid or aqueous the lattice structure is broken and the ions are free to move. As ions are charged, their movement generates a current.*

- *Q12 - Which of the compounds could be separated using electrolysis? Explain why?*
  - *A – All of the ionic compounds (Fe_2O_3, Fe_3O_4 & MgO) can be separated using electrolysis because they contain oppositely charged ions which will move in opposite directions within an electric field. That is to say, the positive metal ions will be attracted to the cathode and the negative non-metal ions will be attracted to the anode.*
- *Q13a - What can be assumed about the reactivity of magnesium compared to lithium?*
  - *A – Lithium is more reactive than magnesium*
- *Q13b - As displacement reactions are REDOX reactions, produce an ionic equation and ionic half equations demonstrate which species is oxidised and which is reduced in the above reaction.*
  - *A –*

$$MgO + 2Li \rightarrow Li_2O + Mg$$

$$Mg^{2+} + O^{2-} + 2\mathrm{Li} \rightarrow 2Li^{+} + O^{2-} + Mg$$

$$Mg^{2+} + 2e^{-} \rightarrow Mg \quad \textit{Reduction}$$

$$2Li \rightarrow 2Li^{+} + 2e^{-} \quad \textit{Oxidation}$$

$$O^{2-} \rightarrow O^{2-} \quad \textit{Spectator}$$

$$Mg^{2+} + 2\mathrm{Li} \rightarrow 2Li^{+} + Mg$$

- *Q14 - The pure iron produced is a metal that is malleable and conducts electricity. With reference to its structure, explain both of the properties.*
  - *A - Metals conduct electricity because their structure contains delocalised electrons which are free to move. As electrons are negatively charged, their movement constitutes a current. Metals are malleable because the lattice of positive ions is able to*

slide easily. As the sea of delocalised electrons will also move, the electrostatic attractions (between positively charged metal ions and the negatively charged sea of delocalised electrons) holding the structure together are maintained.

- *Q15 - What particles enable conduction in metals?*
  - *A – The sea of delocalised electrons.*
- *Q16a - What word best describes this property?*
  - *A – Brittle*
- *Q16b - Which of the given compounds will demonstrate this property?*
  - *A – Ionic compounds will demonstrate this property (Fe_2O_3, Fe_3O_4 & MgO). Diamond will also but it is very strong and hard to apply enough force to cause it to shatter.*
- *Q16c - With reference to their structures, explain why these compounds (16b) demonstrate these properties. You may find a diagram of the structure a useful aid in your explanation.*
  - *A – The application of a large force disrupts the lattice so that one or more of the layers slides. As a result of this, the pattern of alternating ion charge is altered such that like charged ions are brought into close proximity. Consequently, there is electrostatic repulsion and so the lattice 'shatters'.*
- *Q16d - Suggest why magma that cools quickly and suddenly (such as when exposed to the air in a volcanic eruption), have smaller crystals than magma that cools slowly within the crust.*
  - *A – There is less time for lots of bonds (and thus large crystals) to form. (It is also because there is less time at high temperatures – when elements are more mobile – for atoms/ions to move through the magma to the sites of individual crystals to grow them larger).*
- *Q17 - Below is a list of melting points for a number of the given compounds. Using your knowledge of structure and bonding, try to match each of the given melting points with one of the given compounds. Explain your answer for each with reference to the strength and type of bonds holding the structure together.*
  - *A –Students should realise that simple covalent/molecular substances have the lowest MP due to weak intermolecular forces and that giant covalent/molecular substances have the highest due to a large number of strong covalent bonds within the structure. Ionic structures will form the middle ground as ionic bonds are not as strong as covalent.*

MP	Compound	Explanation
-182	*CH_4*	*Simple covalent/molecular bonding. Only enough energy to overcome the weak intermolecular forces is required.*
4,037	*Diamond (C)*	*Giant covalent/molecular structure. There are many strong covalent bonds within the lattice structure which require a large amount of energy to overcome.*

1,377	*Fe_3O_2*	*Ionic*

- *Q18 - CO_2 has a higher MP than CH_4 despite both exhibiting the same type of bonding. Explain why.*
  - *A – Although both compounds bond covalently, CO_2 has a greater molecular mass (Mr) than CH_4 (44 and 16 respectively). Molecules with greater molecular mass tend to have stronger intermolecular forces and so these require more energy to overcome.*

4. Plenary – Word splat

- Write a list of properties/key words on the board such that they are scattered across it. Invite two students to the front and give them a clue for one (or more) of the properties. The winning student is the first one to touch a correct word. An example of a clue might be, "conducts electricity due to the movement of electrons", and the first student to touch the word metal would be the winner.
- Keep the game quickfire and play winner stays on.

5. Homework

- Ask students to produce a list of 20 true or false questions relevant to the structure and bonding chapters. At the start of next lesson get students to test each other using their 20 questions.

Web links

Oxford Sparks video 'Using your science to understand volcanic eruptions':

https://www.oxfordsparks.ox.ac.uk/content/using-your-science-understand-volcanic-eruptions

Further information:

- https://www.sciencemag.org/news/2016/11/smudged-volcanic-crystals-offer-clues-past-eruptions
- ***https://www.tcd.ie/news_events/articles/trinity-scientists-persuade-volcanoes-to-tell-their-stories/***