Suitable for UK KS4 or ages 14-16

Compounds found in Magma: Structure and Bonding

Student worksheet

Introduction

Volcanic activity is the origin of a vast number of minerals used on a day to day basis. Processes deep inside the Earth in places like tectonic plate boundaries can cause rock to melt and rise through the crust towards the surface. This molten rock (magma) is often laden with minerals and trapped gases. As magma rises towards the surface and begins to cool, a number of the minerals crystallise out of solution forming solid crystal structures. Rocks formed by this process are called igneous rocks. Gases within the magma can be trapped as bubbles within rocks or mineral deposits or can escape to the surface (sometimes in violent volcanic events).

Many of the compounds formed by volcanoes have significant commercial and economic value. Understanding the chemistry and formation of such compounds can also be helpful in explaining their properties and helping to predict any future volcanic activity.

In the following resource, you will use your understanding of chemical bonding and structure to explain the properties of a number of chemical compounds associated with volcanic activity (although some, specifically diamond and methane, much more rarely than others!).

Structure and Bonding of Compounds Found in Magma

The following questions will examine the structure and bonding of the following.

SiO_2 CH_4 Diamond (C) Fe_2O_3 CO_2 Fe_3O_2 MgO

1 – Which of the above is <u>not</u> a compound? Explain why.

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2 – By using a periodic table and by looking at the chemical composition of each of the above, suggest the type of bonding responsible for each.

Compound / Element	Type of Bonding
SiO_2	
CH_4	
Diamond (C)	
Fe_2O_3	
CO_2	
Fe_3O_4	
MgO	

3 - Which of the above will have lattice structures?

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4 – Ionic bonding involves the transfer of electrons. Explain why ionic bonding can only occur between a metal and a non-metal?

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5 – Using a dot and cross diagram, show the transfer of electrons in the formation of MgO.

6 – Ionic bonding results in the formation of ions. How do ions differ from atoms?

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7 – What is the name of the force that holds oppositely charged ions together?

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8 – Iron can form many compounds with oxygen. Two examples commonly found in magma are Fe_2O_3 and Fe_3O_4 (also called magnetite). Iron is able to form multiple compounds with oxygen because it is a transition metal and so can exist in a number of 'oxidation states'. That is to say, it can exist as different ions within a compound. As a metal, it typically loses electrons to become 'oxidised' when it bonds. The two most common oxidation states of iron are iron(II) and iron(III) where iron loses 2 or 3 electrons respectively.

8a - Suggest what oxidation state(s) or ion(s) iron is in when it forms Fe_2O_3 (*hint – the compound must be neutral overall*)

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8b - Suggest what oxidation state(s) or ion(s) iron is in when it forms Fe_3O_4 (*hint – the compound must be neutral overall)*

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9 – Some of the above compounds are held together by covalent bonds. What is a covalent bond?

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10 – Draw a dot and cross diagram for a given simple covalent molecule.

11 – Some of the above will conduct electricity. State which and under which conditions. For each, state why it will conduct?

Compound	**Conduct? ✓or ✗**	**State(s) it will conduct?**	**Explanation:** ***What charged particles are free to move and carry a charge?***
SiO_2			
CH_4			
Diamond (C)			
Fe_2O_3			
CO_2			
Fe_3O_2			
MgO			

As magma cools and solidifies, minerals inside crystallise and form rock. Rocks that contain a sufficient amount of a mineral to be economically worth extracting are called ores. Some geologists and Earth scientists apply their knowledge of chemistry and volcanic processes to predict where valuable mineral deposits might form. Some compounds, such as Fe_2O_3, are commonly produced by volcanic activity, while others such as diamond are much rarer as they are thought to only be formed under extremes of pressure and temperature deep in the mantle. Diamonds therefore require deep-source volcanic events to bring them (and magma) up to the crust and depths where they might be extracted. Such events are rare and powerful, and are not typically associated with the volcanic activity of volcanoes on the Earth's surface.

Once formed, a number of commercial techniques can be applied to extract valuable minerals from their ores. Such techniques include electrolysis and displacement.

12 – Which of the compounds could be separated using electrolysis? Explain why?

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13 – REDOX reactions are important in terms of some of the chemistry going on in magmas. Examples of REDOX reactions include displacement reactions, whereby metals can be isolated from their compounds. An example of a displacement reaction involving a given compound is:

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

13a – What can be assumed about the reactivity of magnesium compared to lithium?

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13b – 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.

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Reduction by carbon is another displacement reaction and can be used to acquire iron from Fe_2O_3.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + CO_2$$

14 – The pure iron produced is a metal that is malleable and conducts electricity. With reference to its structure, explain both of the properties.

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15 – What particles enable conduction in metals?

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16 - Due to structures they form, a number of the crystals (e.g., quartz) formed as magma cool can sometimes be shattered when hit with a large force.

16a – What word best describes this property?

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16b – Which of the given compounds will demonstrate this property?

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16c – 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.

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16d – 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.

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17 – Below is a list of melting points for 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.

MP/ °C
4,037
1,377
-72

Compound
CH_4
Diamond (C)
Fe_3O_2

Explanation

18 – CO_2 has a higher MP than CH_4 despite both exhibiting the same type of bonding. Explain why.

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