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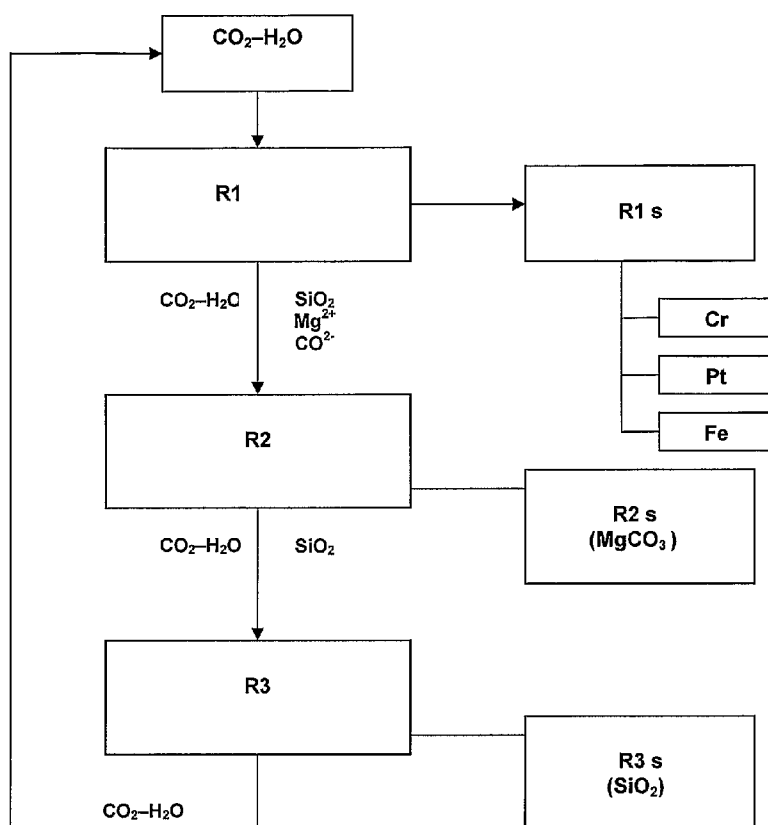
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(54) Title: METHOD FOR INDUSTRIAL MANUFACTURE OF PURE MgCO_3 FROM AN OLIVINE CONTAINING SPECIES OF ROCK

(57) Abstract: Method for industrial manufacture of pure MgCO_3 comprising providing an olivine containing species of rock, to comminute the olivine containing species of rock to increase its surface, to contact the comminuted olivine containing species of rock with water and CO_2 . The process is conducted in at least two steps, namely a first step (R1) at a first pH where a dissolving reacting as represented by the equation: $\text{Mg}_2\text{SiO}_4(\text{s}) + 4\text{H}^+ = 2\text{Mg}^{2+} + \text{SiO}_2(\text{aq}) + 2\text{H}_2\text{O}$, takes place. Then a precipitation takes place in the second step (R2) at a higher pH as represented by the equations: $\text{Mg}^{2+} + \text{HCO}_3^- = \text{MgCO}_3(\text{s}) + \text{H}^+$, and $\text{Mg}^{2+} + \text{CO}_3^{2-} = \text{MgCO}_3(\text{s})$, the presence of HCO_3^- and H^+ ions mainly provided by the reaction between CO_2 and water.



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Method for industrial manufacture of pure MgCO_3 from an olivine containing species of rock

The present invention concerns a method for industrial manufacture of a pure magnesium carbonate (magnesite) from an olivine containing species of rock while immobilizing CO_2 .

- 5 The method allows simultaneous manufacture of other valuable products, hereunder particularly amorphous silica.

Background

- 10 Anthropogenic emission of CO_2 is by many considered to be one of the largest environmental problems in our time. The Kyoto obligations imply various types of fees when CO_2 is released. There is thus a demand for cost-effective methods of handling CO_2 . Injection into water containing or empty petroleum reservoirs has been suggested as a method for deposition/removal of CO_2 in which CO_2 has been used to expel more hydrocarbons from hydrocarbon reservoirs (EOR) is a variant which may involve economical advantages.

- 15 Another possibility is to bind CO_2 as carbonates by reacting CO_2 with species of rock / minerals which contain elements that together with CO_2 provides solid substances/ minerals (carbonates) of which the most relevant elements for the manufacture are Ca, Mg, and Fe.

- 20 CO_2 can e.g. be bound to MgO resulting in precipitation of MgCO_3 . This reaction implies that CO_2 which is produced in industrial processes, like e.g. gas power plants, hydrogen production from natural gas or from methane production, can be immobilized.

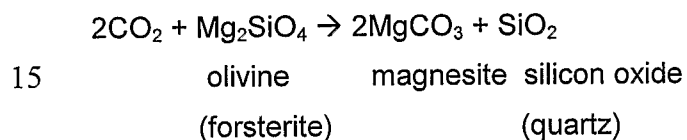
Manufacture of MgO from magnesite (MgCO_3) or dolomite ($\text{CaMg}(\text{CO}_3)_2$) is however not interesting since the production of MgO in these cases will imply formation of the same amount of CO_2 as can be immobilized, hence the net CO_2 effect is zero.

- 25 With regard to the manufacture of MgO from other sources than carbonates, like magnesium containing silicates (sulphates and phosphates) the situation is different. Such a manufacture of MgO only to immobilize CO_2 will however be expensive. ON the other hand the economical potential for such a way to immobilize CO_2 could be significantly improved and possibly be profitable if CO_2 and water in various amounts are brought to
30 react with a species of rock or a mineral in an industrial process where valuable products are formed during the immobilization of the CO_2 . An example of a suitable species of rock is dunite which mainly is comprised by the mineral olivine (+90%), which in Norway is found in large deposits at Sunnmoere and in Nordfjord. (The Aaheim occurrence alone served about 65 % of the world market in 2006). This species of rock has in various acidic

processes been considered as raw material for magnesium production and for production of amorphous silica.

CO₂ with or without various amounts of water, used as an industrial chemical in industrial processes to provide the combined saleable products, MgCO₃, amorphous silica, Fe₂O₃, (Fe, Mg)Cr₂O₄, and Pt, while simultaneously immobilizing CO₂, has not previously been done.

The rock species dunite typically comprises more than 90 % of the mineral olivine. Olivine occurs in a miscible (isomorphous) series in which the most common miscible minerals (end units) are forsterite Mg_2SiO_4 and fayalite Fe_2SiO_4 . In the dunite occurrence in Aaheim the forsterite and fayalite components constitute 93 % and 7 % respectively. Olivine is not stable at the temperature and pressure conditions that exist at the earth surface. This mineral will e.g. react with CO_2 in water under formation of carbonates. In nature, however, this general reaction progresses relatively slow:



The reaction rate can be increased to convenient process rates under laboratory and industrial process conditions and can be optimized by varying pressure, temperature as well as the amount ratio of CO₂ to H₂O.

20 The rock species dunite comprises in addition to the main constituent olivine minerals like
e.g. chromite/ magnesium chromite (Fe, Mg) Cr_2O_4 (0,2-5%) and chrome containing
chlorite. Chromite which is formed at deep levels in the earth crust by solidification of
mafic melts or the uppermost part of the earth mantel (dunite, periodite and other ultra
mafic rock species) also comprises the noble metal platinum and platinum group metals
25 like palladium, osmium, iridium, and ruthenium. Rock species rich in chromite can contain
from 0.1 to 6-7 ppm of platinum group metals. In some cases a content of up to 50 ppm
has been described.

Direct carbonation of olivine has earlier been described as a one-step process (Fauth et al. 2000; O'Connor et al., 2002, 2005). The process makes use of a mixture of water, CO₂ and olivine and the dissolving of olivine and the precipitation of carbonate and silica takes place in one single operation. Experiments have been performed within a temperature and CO₂ pressure of 25-250 °C and 25-250 bars in closed autoclaves. Magnesium carbonate and silica are identified as reaction products. The reaction rate and degree of conversion are low especially at low temperatures and pressures. The effect of grain size, temperature and CO₂ pressure has been systematically investigated. This process, however, gives little ability to distinguish between reaction products.

Multi step processes for carbonation of olivine, serpentine or other silicates have also been investigated. In these processes, however, CO₂ is not included as a reactant in the first step. Blencoe et al (2004) describes a process where silicates are dissolved with lye in a first reaction chamber. The dissolved metal hydroxide is thereafter reacted with gas in a separate reaction chamber for formation of carbonates. In several processes acid is used to dissolve silicates (Maroto-Valer et al., 2005; Park et al., 2005). CO₂ then is added to solution only after silicate minerals have been dissolved in an acidic solution. Dziedic et al (2004) describes a method for dissolving CO₂ in water in which metal ions (Na, Mg, Ca) are added to precipitate salts from the carbonic acid. The method however does not address the problem of how to provide the metal ions.

Objectives

With a basis in the prior art technology it is an object of the present invention to provide a method for cost-efficient production of magnesium carbonate from natural species of rock such as dunite.

It is a further object of the invention to provide a process as mentioned above which can be combined with effective immobilization of CO₂.

It is a further object of the invention to provide a process as mentioned above which is environmentally friendly and which does not require use of strong chemicals such as strong acids.

It is also an object of the invention to provide a method as mentioned above which allows simultaneous manufacture of other valuable products based on the same species of rock.

The invention

The above mentioned objects are achieved by the method as defined by claim 1.

The method according to the present invention provides a simple, rational, cost-effective and environmentally friendly process for production of highly pure magnesium carbonate from natural sources of dunite (olivine).

The method according to the present invention is a process comprising at least two steps in which the first step can be denoted a dissolution process. Thus, magnesium from forsterite, which is the major constituent of olivine, is dissolved in this first step of the process. However, already in this first step of the process precipitation in the form of iron hydroxides occurs as iron will always be present in natural occurrences of dunite/ olivine.

In a second step highly pure magnesium carbonate is precipitated as shown in the following examples. The conditions of step 2 can, like in step 1, vary significantly, but it is a characterizing feature of step 2 that a pH higher than the pH of step 1 is used. As

elaborated below the pH adjustment may be preformed without addition of further chemicals in the process.

The method according to the invention does not require use of strong reagents and is generally only based on the reaction between CO₂, water and the species of rock in

5 question I an appropriate combination.

It is preferred that the method according to the present invention also comprises isolation of amorphous silica by precipitation which most conveniently takes place in a step subsequent to the step of precipitation of magnesite. While precipitation of magnesite largely is decided by pH, precipitation of silica is largely decided by temperature. Careful control
10 with these parameters allows quantitative isolation of each of said components in separate steps.

Figure 1 is a flow chart which schematically shows the general steps of the process according to the present invention.

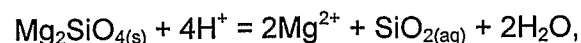
Figure 2 is a flow diagram showing the layout for the experiment described in Example 1.

15 Figure 3 is a flow diagram showing the layout for the experiment described in Example 2.

Figure 4 are plots showing calculated reaction rates for dissolution of olivine in the examples.

Figure 1 shows how CO₂ from a source which can be a combustion plant or any other CO₂ source is combined with water in the uppermost box in Figure 1. Then dunite is added to or combined with this mixture in a reactor chamber denoted R1. The dunite is before or in
20 the reactor R1 comminuted to obtain a large surface to volume ratio. In water CO₂ forms carbonic acid. CO₂ has however limited solubility in water and higher solubility at high pressure than at low pressure. If sufficient CO₂ is added so that the water at all times is saturated with CO₂, the pH in the solution will be a direct function of pressure.

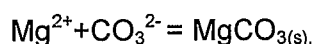
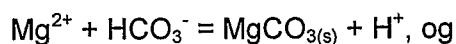
25 In the first step, R1, of the process forsterite is dissolved in a way that can be represented by the equation:



This reaction is sufficiently fast for industrial purposes within a broad range of pressures and temperatures but requires a pH in the acidic range and therefore a certain
30 overpressure (in order to dissolve a convenient amount of CO₂) to provide an optimal result. Present iron from fayalite and other sources which in this context is to be considered as contaminations in the process, are already in this step dissolved and precipitated as hydroxides and possibly oxides.

Solid material from the first step in the form of non-reacted, solid components and
35 precipitated material from iron as mentioned above and possibly other precipitated

materials, are separated out to R1 s before the liquid reaction mixture is transferred to next step R2. The solid material in R1 s can optionally be refined further to other end products such as chrome, iron and small amounts of Pt. The liquid reaction mixture which is rich in magnesium ions, is transferred to next step, R2, which has a higher pH than the first step for thereby facilitate the precipitation of magnesium as magnesite. According to the present invention the second step R2 is conducted at a pH which is higher than that of the first step R1, and the required pH adjustment is feasible solely by means of a pressure reduction of the reaction mixture so that the amount of CO₂ dissolved in the water is automatically reduced with implies a reduction of concentration of carbonic acid in the water. It is possible within the scope of the invention also to adjust pH chemically, but the process then becomes less environmentally friendly. Precipitation of magnesite furthermore is favoured by high temperature and therefore the temperature of process step 2 is preferably higher than the temperature of process step 1. Precipitation can also be conducted without pressure adjustment between process step 1 and 2. Higher temperature generally gives a higher pH. The reaction in second step R2 can be described as follows:



The solid magnesite material, MgCO_{3(s)}, is received in R2 s for optional post-treatment, storage and shipment. For certain embodiments it can be relevant to produce pure (elementary) magnesium from this product.

Between first and second process step it is possible but not required to recycle part of the reaction mixture to the first process step.

It is usually desirable to collect silicon that enters the process in a way which allows it to be included as a valuable component in various products. This is most conveniently done through a third process step R3 as shown in Figure 1 and which directly succeeds process step 2. Precipitation of silicon as amorphous silica is rather independent of pH but is favoured by low temperature. It is therefore convenient that the temperature is lowered from step R2 to the optional step R3. Prior to the precipitation of silica it may be convenient to evaporate the solution to a higher silica concentration. The precipitated amorphous silica is received in R3 s. Remains of liquid material from process step are recycled to a previous step of the process, most preferably to process step 1. Also between R2 and R3 it is possible to withdraw a certain amount of the liquid process flow for recycling (not shown).

Below the most typical uses of the different product components are briefly indicated but it should be emphasized that the present invention is not restricted to only such uses or products.

5 Solid components from step 1 mostly comprise iron but typically also smaller amounts of chrome and platinum group metals as mentioned. These components can be used for isolation of the pure respective metals which again may be used to make a product based on such metals.

Magnesite or magnesium carbonate from step 2 is used as a filler in paper and plastic products.

10 Silica can also be used as filler in some connections such as in car tyres but can also be used for manufacture of silicon metal which is very valuable if it can be produced with high purity.

As already mentioned the present invention only requires adjustment of pH in the form of addition of CO₂ in water and adjustment of pressure. It is thus possible but hardly
15 desirable, to add strong mineral acids or strong organic acids so facilitate the dissolving of minerals in the species of rock. It is required to crush the species of rock in order to obtain a progress sufficient for an industrial process. It is preferred that the species of rock is comminuted to a particle size where (the largest dimension of) each particle is less than 3 mm, more preferred less than 0.5 mm and in some applications less than 0.1 mm. In a
20 conventional crushing process grinding, sieving, recycling, repeated grinding and repeated sieving makes it possible to ensure that all particles are within the defined limit for the particle size if so desired. It should be emphasized though, that no absolute requirements to the particle size is present with the present invention. The invention will work well if e.g. 80 % of the volume of particles are within an indicated grain size limit.

25 In the first process step the pH should be in the acidic range, i.e. lower than about 7. It is preferred that pH in this step is in the range 3-5, though even lower pH values are acceptable. In the first reactor or reactor chamber a typical pressure is in the range 1-200 bar, more preferred 20-170 bar and most preferred in the range 50-150 bar. In the same process step the temperature preferably is in the range 50-220 °C and more preferred in
30 the range 100-170 °C.

In the second process step the pH is always higher than in the first process step. The pressure in the second reactor is typically in the range 1-150 bar, more preferred 20-130 bar and most preferred 50-80 bar. In the same step the temperature preferably is in the range 100-300 °C, more preferably 140-250 °C.

There are different ways of separating the individual process steps from each other. In a continuous process however, it is required to use separate reactors or separate reactor chambers for each process step in order to maintain mainly constant conditions within each reactor or each individual reactor chamber. Thus the first process step takes place in a first reactor chamber while precipitation of magnesium carbonate takes place in another reactor chamber which solely receives liquid material from the first reactor chamber while non-reacted reactant and precipitated bi-products in first reactor chamber are first separated from.

As previously mentioned the pressure is preferably reduced from first reactor chamber to second reactor chamber so that some CO_2 thereby is released from the solution and pH is correspondingly increased. Furthermore the temperature is preferably increased from first to second reactor chamber for thereby favouring precipitation of MgCO_3 .

When the process comprises a third process step comprising precipitation of amorphous silica, this typically takes place at a lower temperature than the temperature of process step 2.

The olivine containing species of rock used preferably is dunite.

The process typically is conducted as a continuous process with respect to the liquid flow in the process and more preferred the entire process is conducted as a continuous process.

Iron oxides/ hydroxides together with insoluble chromite which typically contains PGE are discharged from the dissolution reactor (process step 1) for further treatment in a production plant for manufacture of iron, chrome and platinum group metals.

It should be emphasized that the method according to the present invention also is valuable because it comprises a step of immobilizing CO_2 which in large amounts is an undesired greenhouse gas and which constantly will represent a challenge to handle because the traditional energy production and car use will continue to produce large amounts of CO_2 all over the world.

Examples

Two examples are provided. These examples demonstrate step one and a connection between step one and step two of the process. For both examples olivine from North Cape Minerals, denoted GL50, were used. The olivine shows $X_{\text{Mg}} = \text{Mg}/(\text{Mg} + \text{Fe}) = 0.93$.

A semi-continuous process layout with continuous liquid through-put while solid material was held back in the reactors, was used. At high pressure, high temperature and constant flow rate, CO_2 and H_2O are pumped into an autoclave to be mixed. The solution comprising water with dissolved CO_2 is thereafter directed to a dissolution reactor in which

it is brought to react with olivine. Filters are arranged in the dissolution reactor to prevent solid particles from leaving the reactor.

For Example 1 the aqueous solution was fed to the dissolution reactor via a back pressure valve to fluid sampling at room temperature and atmospheric pressure. The experimental layout of Example 1 is shown in Fig. 2.

For Example 2 the aqueous solution was directed from the dissolution reactor to a precipitation reactor for crystallization of magnesite. Also in this reactor filters were arranged to prevent solid particles from leaving the reactor. Downstream of the precipitation reactor the solution was directed through a back pressure valve to fluid sampling at room temperature and atmospheric pressure. The experimental layout for Example 2 is shown in Fig. 3.

Example 1. Dissolution of olivine in step 1.

A series of three experiments was conducted (Table 1). Two of the samples were crushed, dry, in a planet mil with different crushing times. The third sample was carefully crushed in a mortar and sieved and the fraction between 75 and 150 µm was used.

The conditions for all these experiments were 130 °C and 150 bar. A total flow rate of 0.75 ml/ min in the amounts 0.71 ml/min H₂O and 0.04 ml/ min CO₂ were used. All parts of the experimental layout were equilibrated to high temperature and high pressure before the sample was injected into the dissolution reactor.

The reaction rate was calculated from the following equation:

$$Rate = \left(\frac{Conc_i}{\nu_i} \right) \cdot \left(\frac{FR}{A} \right)$$

In which $Conc_i$ is the concentration of Mg or Si in the water samples, ν_i are stoichiometric coefficients in olivine, 1.85 for Mg and 100 for Si respectively; FR is flow rate and A is surface area analysed with BET.

An abstract of the experiments are shown in Table 1. Remaining solid material in the reactor after the experiments is comprised by chromite, remains of olivine or other silicates and iron hydroxides. The reaction rate is shown in Fig. 4. Calculated reaction rates are not corrected for changes in surface area during the experiment. The correlation between reaction rate calculated on basis of Mg and Si in Figure 4 shows that the dissolution reaction is congruent which means that the dissolution of olivine is stoichiometric

(complete). The weight loss of solid material in the experiments varies between 67 % and 98 %.

Table 1: Overview of the dissolution tests

Experiment	Pre-preparation	Weight before	BET before	Weight loss	Weight loss	Duration
		g	m ² /g	g	%	hours
Olivine 11	Planetary mill, 10 min, dry	0.49	4.32	0.34	70	45
Olivine 12	Planetary mill, 60 min, dry	0.48	3.19	0.32	67	28
Olivine 14	sieved, 75-150 µm	1.14	0.87	1.12	98	76

Example 2. Connection between step one and precipitation of magnesite in step two

In this test a packed column was used as a dissolution reactor. The conditions for dissolution was the same as in the previous example, 130 °C and 150 bar and a total flow rate of 0.75 ml/ min in the amounts 071 ml/min H₂O and 0.04 ml/ min CO₂.

The aqueous solution was led directly into a precipitation reactor in which the temperature was 250 °C and the pressure was 150 bar. Only magnesite was precipitated at this stage. Crystals of up to 500 µm were formed. There was no agitation in the precipitation reactor.

Analyses of the magnesite are shown in Table 2. The analyses were conducted with a micro probe. The method has few possibilities of determining the content of the heavy elements (Ca, Fe, Mg, Mn) and the CO₃ content therefore is calculated from stoichiometry.

Table 2: Mineral chemistry of precipitated magnesite

Item No	#1	#2	#8	#9
Sample	OI20-R2	OI20-R2	OI20-R2	OI20-R2
weight %				
CaCO ₃	0.012	0.032	0.025	0.055
FeCO ₃	0.202	0.102	0.037	0.005
MgCO ₃	99.275	99.275	99.336	99.440
MnCO ₃	0.060	0.031	0.079	0.000
	99.549	99.439	99.477	99.500

Table 2 shows a high level of purity for the manufactured magnesite, in the range from 99.275 to 99.440 %. In general the examples show that the invention provides results as described and that it is possible to manufacture valuable products from a species of rock while simultaneously immobilizing CO₂.

Other aspects of the present invention

Using dunite as a source of magnesium a highly convenient combination of industrial, hydro metallurgic processes in which a CO₂-H₂O mixture acts as a process chemical is obtained. The CO₂ is immobilized and bound in a solid material (MgCO₃) which can be deposited or used, this second aspect of the invention briefly stated concerns:

- CO_2 in the form of carbonate is used as anion for crystallization of the extracted magnesium (immobilization of CO_2)
- extracted, amorphous SiO_2 manufactured as raw material for the production of silicon metal and used directly as filler in e.g. car tyres.
- extracted Fe_2O_3 and Pt containing $\text{Mg, Fe)Cr}_2\text{O}_4$ are manufactured as raw material for the metals Fe, Cr and Pt.

Method for combining immobilization of CO_2 from a combustion plant or another CO_2 source, e.g. a power plant powered by fossil fuel and where a magnesium containing, carbonate free species of rock, e.g. a silicate species of rock such as dunite or other olivine containing species of rock such as peridotite or similar mineral/ species of rock is brought to react with a $\text{CO}_2\text{--H}_2\text{O}$ mixture to produce a solution with magnesium and carbonate ions and amorphous silica under continuous and dynamic reaction conditions in the temperature range 50-300 °C and the pressure range 1-200 bar. The process is so arranged that the dominating material olivine in the rock type dunite or other olivine containing rock types is dissolved in a dissolution reactor so that the main part of the iron in the mineral olivine remains in the dissolution reactor as iron oxide/ iron hydroxide together with insoluble PGE containing (platinum group metal containing) chromite ($\text{Mg, Fe) Cr}_2\text{O}_4$. The magnesium and silicon containing solution is brought to precipitation reactors for precipitation of iron free or iron poor magnesium carbonate and amorphous SiO_2 respectively, the magnesium carbonate being precipitated in the first precipitation reactor at temperature conditions in the range 100-300 °C and pressure conditions in the range 1-200 bar at a pH of 5-13, while amorphous silica (SiO_2) is precipitated in the second precipitation reactor at temperature conditions in the range 20-300 °C and pressure conditions in the range 1-200 bar.

Method as claimed in the paragraph above in which the iron oxides / hydroxides together with insoluble PGE containing chromite ($\text{Mg, Fe) Cr}_2\text{O}_4$ are discharged from the dissolution reactor for further treatment in a production plant for the manufacture of iron, chrome and platinum group metals.

Method in accordance with the two above adjacent paragraphs in which CO_2 is immobilized in magnesium carbonate (MgCO_3) which is discharged from the precipitation reactor either for deposition or for further treatment for use as filler e.g. in paper or plastic industry or as a raw material for magnesium production.

Method in accordance with the three above adjacent paragraphs in which the amorphous SiO_2 is discharged from the precipitation reactor and treated further e.g. with acid for

manufacture of various amorphous SiO₂ qualities for use as filler in car tyres or as raw material for the manufacture of silicon.

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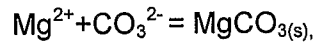
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Claims

1. Method for industrial manufacture of pure MgCO_3 comprising providing an olivine containing species of rock, to comminute the olivine containing species of rock to increase its surface, to contact the comminuted species of rock with water and CO_2 , characterized in that the process is conducted in at least two separate steps, namely a first step at a first pH in which a dissolving reaction generally takes place according to the reaction equation:



after which a precipitation is conducted in a second step at a higher pH, the reaction in said second step generally being represented by the reaction equations:



the presence of HCO_3^- and H^+ ions mainly being due to the reaction between CO_2 and water.

2. Method as claimed in claim 1, **characterized in** that the olivine containing species of rock is comminuted to a general grain size less than 3 mm, more preferred less than about 0.5 mm and most preferred less than 0.1 mm.

3. Method as claimed in claim 1 or 2, **characterized in** that pH in said first step is in the range 3-5 while pH in said second step for precipitation of magnesium carbonate is in the range 5-13.

4. Method as claimed in any one of claims 1-3, **characterized in** that iron that accompanies the raw material is precipitated as iron hydroxide in first step.

5. Method as claimed in any one of claims 1-4, **characterized in** that the first step is conducted in a first reactor chamber and precipitation of magnesium carbonate is conducted in another reactor chamber which solely receives liquid material from the first reactor chamber while non-reacted reactant and precipitated bi-products in first reactor chamber are separated out.

6. Method as claimed in claim 1, characterized in that the pressure is reduced from the first reactor chamber to the second reactor chamber so that some CO_2 thereby is released from the solution and the pH correspondingly increased.

7. Method as claimed in claim 1, **characterized in** that a higher temperature is used in the second reactor chamber than in the first reactor chamber to thereby favour precipitation of MgCO_3 .

8. Method as claimed in any one of the preceding claims, **characterized in** that a three step process is used and that the third step is one of precipitating amorphous silica (SiO_2).

9. Method as claimed in claim 5 (should be 8), **characterized in** that SiO_2 is precipitated from the reaction mixture after that MgCO_3 has been precipitated and at a lower temperature.
10. Method as claimed in claim 1, **characterized in** that the pressure in the first reactor is in the range 1-200 bar, more preferred 20-170 bar and most preferred from 50-150 bar.
11. Method as claimed in claim 1, **characterized in** that the temperature in the first reactor is in the range 50-220 °C, more preferred in the range 100-170 °C.
12. Method as claimed in claim 1, **characterized in** that the pressure in second reactor is in the range 1-150 bar, more preferred 20-130 bar and most preferred from 50 to 80 bar.
13. Method as claimed in claim 1, **characterized in** that the temperature in the second reactor is in the range 100-300 °C, more preferred in the range 140-250 °C.
14. Method as claimed in claim 1, **characterized in** that the olivine containing species of rock is Dunite.
15. Method as claimed in claim 1, **characterized in** that the process is conducted as a continuous process with respect to the liquid flows of the process.
16. Method as claimed in claim 15, **characterized in** that the process is conducted as a wholly continuous process.
17. Method as claimed in claim 1, **characterized in** that the dissolving reaction takes place in absence of strong mineral acids and strong organic acids.
18. Method as claimed in claim 1, **characterized in** that the comminuted species of rock has a particle size less than 0.1 mm, that the pressure in the first reactor is in the range 50-150 bar, that the pressure in the second reactor is in the range 50-80 bar, that pH in the first reactor is in the range 3-5, that pH in the second reactor is in the range 5-13, that the temperature in the first reactor is in the range 100-170 °C, that the temperature in the second reactor is in the range 140-250 °C, that the process is run free from acid other than CO_2 dissolved in water and that the process is run as a continuous process.
19. Method as claimed in claim 1, **characterized in** that MgCO_3 is used as a raw material for production of Mg or as a filler in other products such as paper and plastic products.
20. Method as claimed in claim 1, **characterized in** that SiO_2 is used as a raw material for the manufacture of various amorphous SiO_2 qualities, as a raw material for the manufacture of silicon or as a filler in other products such as car tyres.
21. Method as claimed in claim 1, **characterized in** that iron oxides/ iron hydroxides together with insoluble PGE containing chromite is discharged from the dissolving reactor

for further treatment in a production plant for the manufacture of iron, chrome and platinum group metals.

22. Method as claimed in claim 1, **characterized in** that the method is also used to immobilize industrial quantities of CO₂ as carbonate in valuable end and intermediate products.
- 5

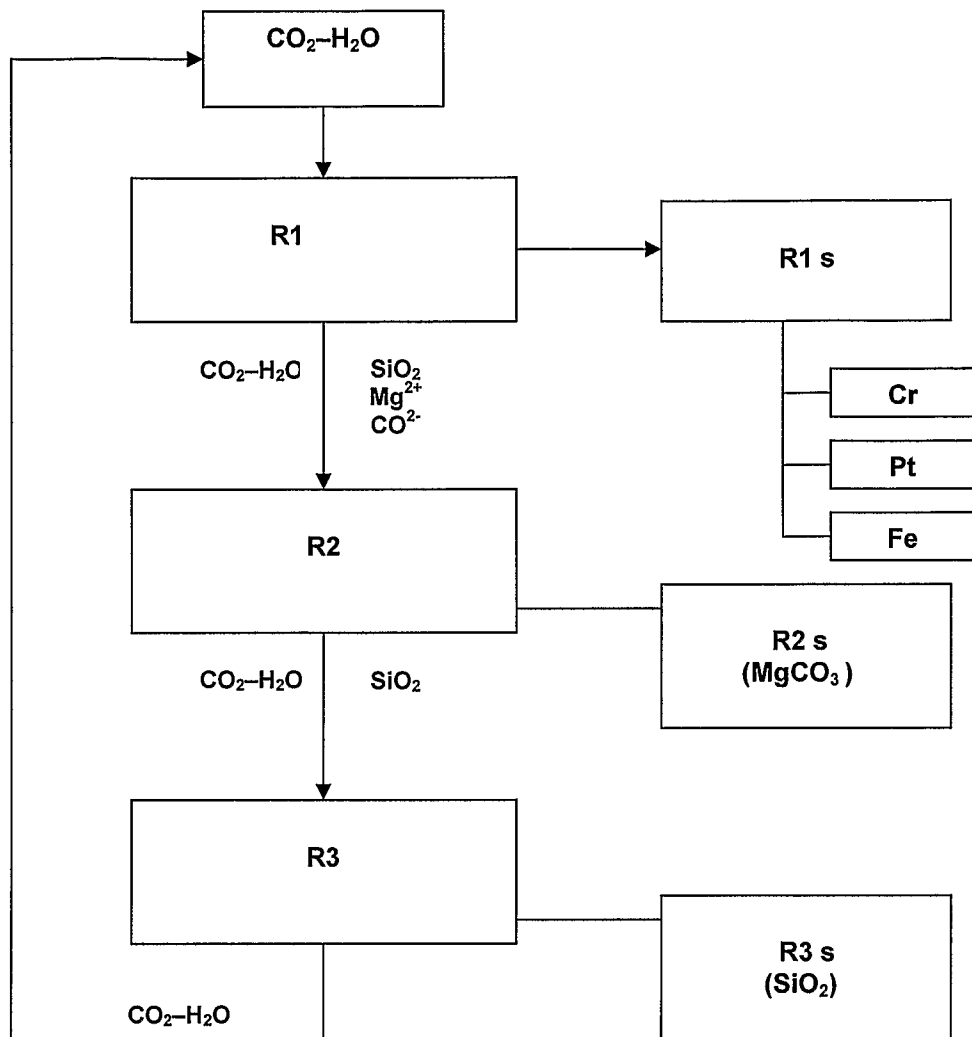
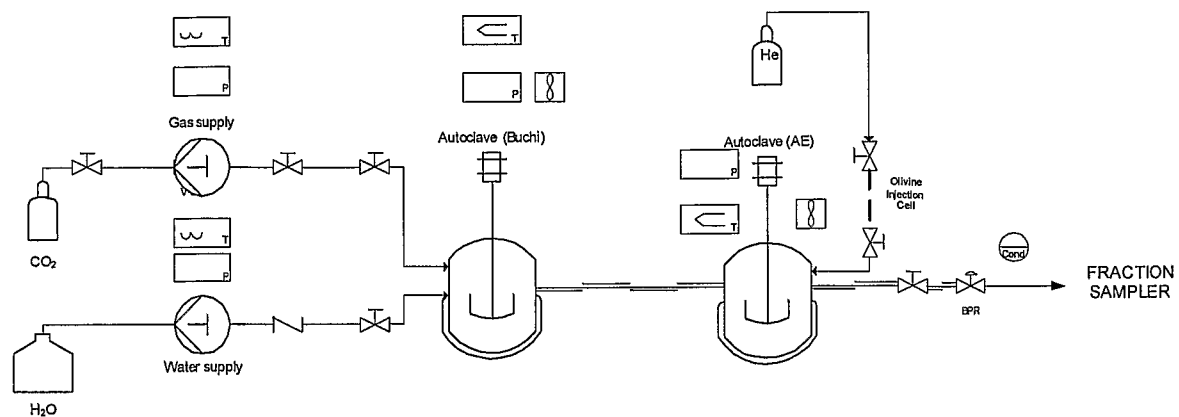
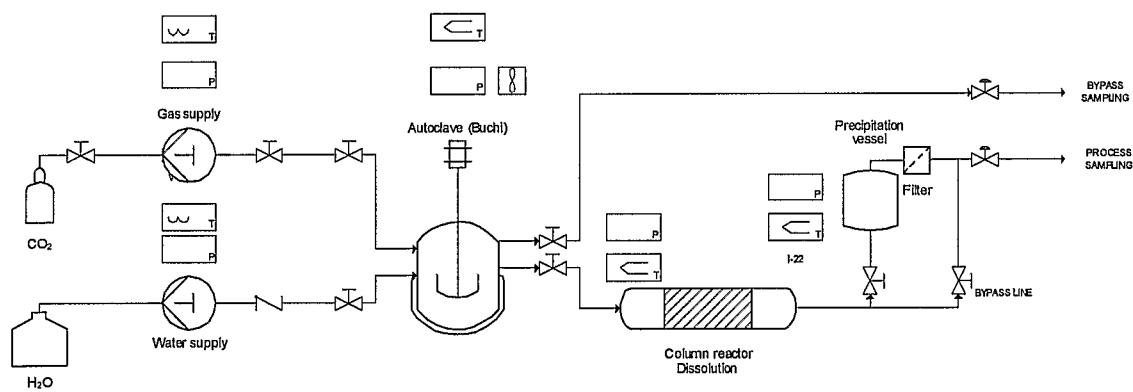
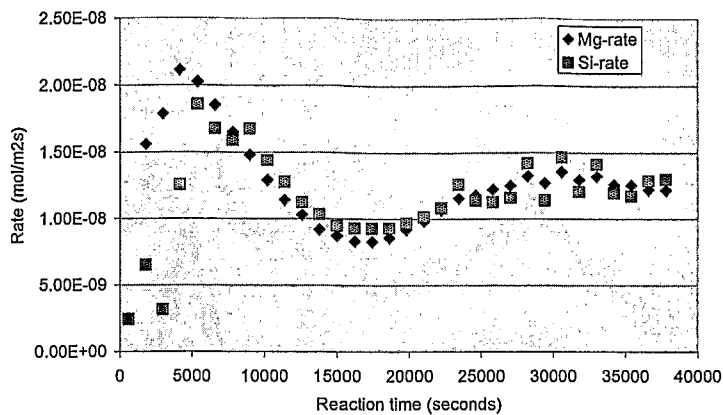


Fig. 1

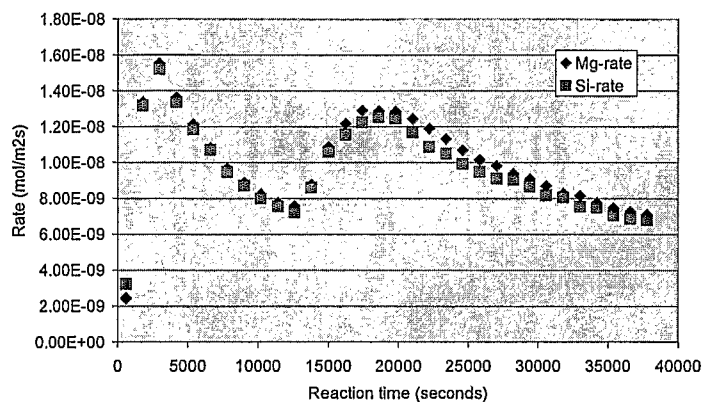
**Figure 2****Figure 3**

3/3

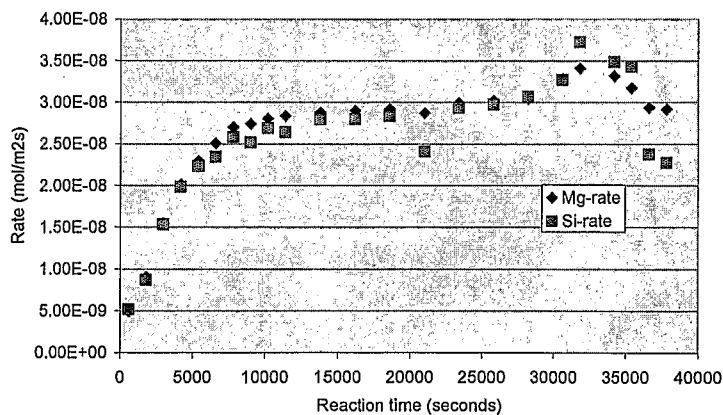
Olivin-11



Olivin-12



Olivin-14



Figur 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2006/000427

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20050180910 A1 (PARK, AH-HYUNG ET AL), 18 August 2005 (18.08.2005) --	1-22
A	O'CONNOR, W.K. ET AL, "Carbon dioxide sequestration by direct mineral carbonation: process mineralogy of feed and products", Minerals & Metallurgical processing, 2002, vol. 19, no. 2, page 95 - page 101 -- -----	1-22

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

12 March 2007

Date of mailing of the international search report

13 -03- 2007

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Use the application number as username.

The password is **CYULXXAQNW**.

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT
Information on patent family members

26/01/2007

International application No.

PCT/NO2006/000427

US 20050180910 A1 18/08/2005 NONE
