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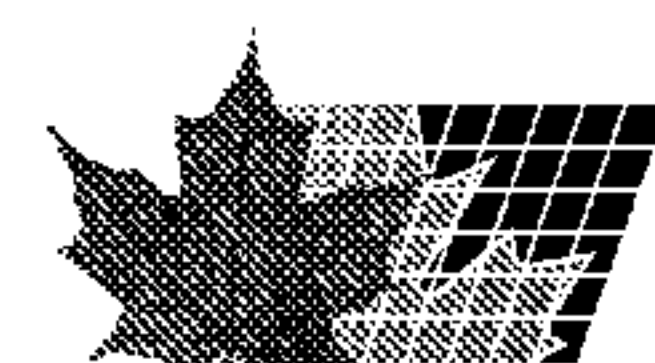
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(54) Titre : COMPOSES METAL-MAGNESIUM, PROCEDE DE PREPARATION DE TELS COMPOSES ET UTILISATION DE CES DERNIERS AUX FINS DE PREPARATION DE POUDRES METALLIQUES FINES ET DE COMPOSES INTERMETALLIQUES

(54) Title: METAL-MAGNESIUM COMPOUNDS, PROCESS FOR PREPARING SAME AND THE USE THEREOF FOR THE PREPARATION OF FINELY DIVIDED METAL AND ALLOY POWDERS AND INTERMETALLIC COMPOUNDS

(57) **Abrégé/Abstract:**

The present invention relates to metal-magnesium compounds, a process for preparing same and the use thereof, especially for the preparation of finely divided, possibly amorphous, metal and alloy powders and/or of intermetallic compounds, both procedures via a non-metallurgical route in organic solvents under mild conditions.



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Abstract of the Disclosure

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The present invention relates to metal-magnesium compounds, a process for preparing same and the use thereof, especially for the preparation of finely divided, possibly amorphous, metal and alloy powders and/or of intermetallic compounds, both procedures via a non-metallurgical route in organic solvents under mild conditions.

Metal alloys and/or intermetallic compounds are usually prepared by metallurgical processes. Metal powders in a finely divided highly reactive form are obtained according to DE 35 41 633 (Studiengesellschaft Kohle, 1987) by reacting metal salts in a solvent with magnesium powder which has been admixed with a catalytic amount of anthracene and/or of magnesium anthracene or one of the derivatives thereof as an activator. According to the DE 36 13 532 (Studiengesellschaft Kohle, 1987)

there has been known a process for the preparation of finely divided, possibly amorphous, intermetallic compounds and the hydrides thereof, wherein hydrides of the elements of the Main Groups I to IV of the Periodic Table, hydridemagnesium halides or magnesium dialkyls in an organic solvent are reacted with bisallylmetal compounds of the metals of the Subgroup VIII of the Periodic Table or of zinc. A recently described method for the preparation of finely divided metal and alloy powders {H. Bönemann et al., Angew. Chem. 102 (1990), 324} consists of the reduction or co-reduction of metal salts in an organic phase by means of alkali metal or alkaline earth metal organohydridoborates.

Now, surprisingly a new process was found for the preparation of metal-magnesium compounds (M^1 -Mg-compounds), and by employing these, of metal and alloy powders or of intermetallic or metal-element compounds (M^1 , M^1M^2 , $M^1M^2M^3...$) in a finely divided highly reactive and possibly amorphous form. The new process relating to M^1 -Mg-compounds is characterized in that halides of the metals of the Groups IIIA-VA, VB-VIIB, VIII, IB and IIB of the Periodic Table (M^1X_m), or optionally the metals M^1 or M^1 -hydrides, are reacted in an organic solvent with magnesium hydride (MgH_2), hydridemagnesium halides ($HMgX$), organomagnesium compounds and/or metallic magnesium, if desired in the presence of anthracene or its derivatives, magnesium anthracene · 3 THF (MgA) or its derivatives, magnesium halides, organic halides and/or quinuclidine as activators. Tetrahydrofuran (THF) is deemed to be the preferred solvent. The metals M^1 are preferred to be employed in a finely divided highly reactive form, while it is desirable that the magnesium component used has

preferably been dissolved or partially dissolved in an organic solvent, or that an insoluble magnesium component (e.g. magnesium powder) is employed in the presence of said activators. As the MgH_2 , there is preferably employed the catalytically prepared MgH_2 (MgH_2^* ; European Patent 3564, Studiengesellschaft Kohle, 1982) or the catalytically prepared dissolved MgH_2 (MgH_2' ; DE 37 22 993, Studiengesellschaft Kohle, 1989). As the preferred organomagnesium compounds, there are contemplated $\text{C}_1\text{-C}_{12}$ -alkylmagnesium halides, di- $\text{C}_1\text{-C}_{12}$ -alkylmagnesium compounds, MgA or its alkyl or aryl derivatives and/or $\text{Mg}_2\text{Cl}_3(\text{THF})_6^{\oplus}\text{-anthracene}^{\ominus}$.

It is considered a pre-requisite for the preparation of $\text{M}^1\text{-Mg}$ compounds from metal halides M^1X_m according to the present invention that an excess of the magnesium compound is employed relative to the quantity required for reducing M^1X_m to the metal level M^1 or to form a M^1 hydride. Namely, in this procedure, part of the Mg component is consumed for the reduction of M^1X_m to the metal stage or for the formation of M^1 hydride, whereas the excess of the Mg-component reacts with the metal M^1 or with the M^1 hydride in statu nascendi to form the $\text{M}^1\text{-Mg}$ compound. Therefrom it ensues that in the reaction of M^1X_m with the Mg component, depending on the molar ratio of M^1X_m :magnesium component and on the reaction conditions, both M^1 or M^1 hydride, $\text{M}^1\text{-Mg}$ compounds in admixture with M^1 or M^1 hydride and $\text{M}^1\text{-Mg}$ compounds alone may be formed. Nevertheless, the preparation of $\text{M}^1\text{-Mg}$ compounds may also be carried out in two steps, if so desired, wherein first M^1X_m , with the Mg component, is reduced to the metal level M^1 or converted into the M^1 hydride, and then the resulting M^1 or M^1 hydride, which is present in a finely divided

highly reactive form, is subsequently reacted with a further amount of the Mg component in a solvent, or in the solid state by means of a subsequent thermal treatment, to form the M^1 -Mg compound.

In the reaction of M^1X_m (or of M^1) with the Mg components mentioned according to the present process, the types a.-d. listed hereinbelow of M^1 -Mg compounds may be formed, depending on the kind of M^1X_m (or of M^1) and of the Mg component and on the molar ratio and reaction conditions employed:

- a. intermetallic Mg compounds or Mg alloys ($Mg_xM^1_y$);
- b. intermetallic Mg hydrides ($Mg_xM^1_yH_p$),
carbides ($Mg_xM^1_yC_q$)
and hydride-carbides ($Mg_xM^1_yH_pC_q$);

the M^1 -Mg compounds listed in a. and b. comprise known compounds of the respective types as well as compounds hitherto unknown. It is characteristic for the instant process that the resulting compounds are formed in a highly reactive, finely divided and possibly X-ray amorphous form.

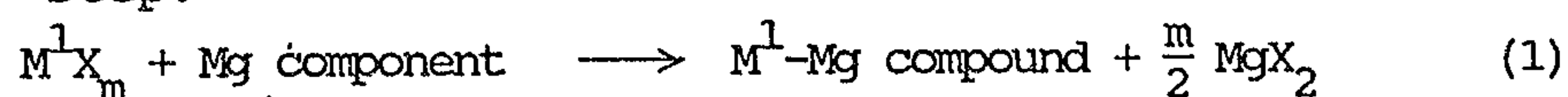
Of special novelty is the finding that according to the present process there can be formed not only solid intermetallic Mg compounds or Mg alloys, but in many cases also the hitherto unknown THF-soluble M^1 -Mg compounds, namely

- the THF-soluble M^1 -Mg halides (Type c.), and
- the THF-soluble M^1 -Mg (hydride)halides (Type d.).

It has further been found that the Mg in the M^1 -Mg compounds preparable according to the present process

may be replaced by an alien metal or element M^2 or by two or more alien metals or elements ($M^2, M^3 \dots$) by allowing M^1 -Mg compounds to react with M^2 halides (M^2X_n) or with a mixture of M^2 and M^3 halides, preferably in a solvent. Thus, in combination with the method presented for the preparation of M^1 -Mg compounds of the types a. through d., for the first time there ensues a purposeful two-step synthesis of intermetallic compounds as well as metal-element compounds or metal alloys ($M^1M^2, M^1M^2M^3, \dots$) under mild conditions ("cold metallurgy") and without employing the otherwise conventional, expensive metallurgical processes. The preparation of (M^1M^2) in accordance with this two-step synthesis may be described by the following equations:

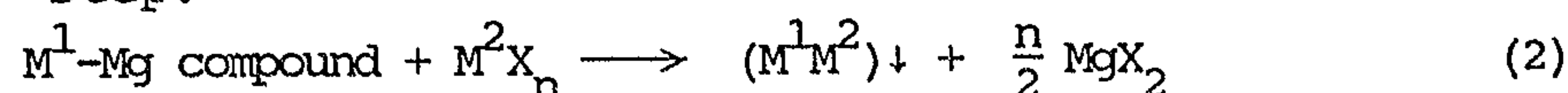
1st Step:



Optional 1st Step:



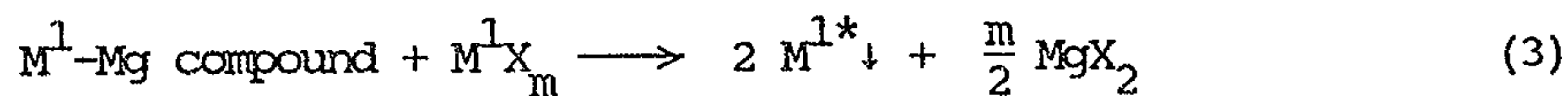
2nd Step:



If so desired, the preparation of (M^1M^2) according to this method may be carried out also in one step (Example 22a) by allowing to react M^1X_m with the magnesium component in the presence of M^2X_n .

For the preparation of $M^1M^2, M^1M^2M^3$ according to the presented method there may also be employed the M^1 -Mg compounds preparable according to the DE 36 13 532 (Studiengesellschaft Kohle, 1987).

If, according to the presented method, the M^1 -Mg compounds are reacted with M^1X_m , then the metals M^1 are obtained in a finely divided highly reactive form:



The preparation of the $M^1\text{-Mg}$ compounds a. through d. and the use thereof for the production of metal and alloy powders and of intermetallic compounds (M^1 , M^1M^2 , $M^1M^2M^3$) is furnished evidence of by the Examples 1 through 41, while it is not limited thereto. Examples for the preparation of $M^1\text{-Mg}$ compounds according to Equation 1 have been set forth in the Tables 1 to 4 and 4a, and examples for the preparation of metal alloys (M^1M^2) according to Equation 2 and of the metal powders (M^{1*}) according to Equation 3 have been set forth in the Tables 5 and 5a.

The soluble or insoluble $M^1\text{-Mg}$ compounds preparable according to the instant process may be used as, inter alia, homogeneous or heterogeneous catalysts, as starting materials for the preparation thereof or for the preparation of organometallic M^1 compounds. Thus, for example, the Mg-Sn, Mg-Pb and Mg-Ga alloys accessible according to the process may be employed as starting material for the preparation of organotin compounds (herbicides, pesticides), organolead compounds (knock inhibitors) and organogallium compounds (Ga, As, photo-voltaic cells). The intermetallic Mg hydrides (compounds of type b.) and especially the THF-soluble $M^1\text{-Mg}$ (hydride)halides (type d.) such as, e.g., $Fe(HMgCl)_2$ (Example 21) may be used as reducing agents for functional organic compounds such as, e.g., esters, ketones, aldehydes, halides and the like. The solid $M^1\text{-Mg}$ compounds may find use as metal and alloy powders in the powder technology (e.g. Mg_2Cu), and the hydrides and carbides thereof may find use as reversible hydrogen and heat storage media, where it is an advantage that

according to the instant process they are obtained in a highly active, finely divided and often X-ray amorphous form. Besides, the M^1 -Mg compounds according to Equations 2 and 3 are employed as starting materials for the preparation of metal and alloy powders (M^1 , M^1M^2 , $M^1M^2M^3$, ...) in a finely divided, highly reactive form. The metal and alloy powders (M^1 , M^1M^2 , ...) are also usable in powder technology and especially as heterogeneous catalysts (e.g. FeCu, Example 21, as catalyst for the Fischer-Tropsch synthesis).

The advance in the art constituted by the instant process is also due to the fact, besides other reasons, that intermetallic M^1 -Mg compounds and alloy powders (M^1M^2 , ...) have become accessible which according to the hitherto common metallurgical procedures could be produced not at all or only at a higher expenditure. Thus, for example, the intermetallic compound Mg_2Pt (Example 12) which reversibly reacts with hydrogen is hardly ever accessible via a metallurgical route. The new intermetallic compounds, the tetragonal $MgPt$ and Mg_2Pt could not be produced via the metallurgical route.

Figure 1 shows a powder diagram of Mg_2Pt measured with a sample of Example 17. Also shown for comparison are the calculated diagrams for Mg_2Pt and $MgPt$. It is evident that the examined sample contains both compounds.

Figure 2 shows a powder diagram of $MgPt$ measured with a sample of Example 18. Also shown for comparison is the calculated diagram for $MgPt$. It is evident that the examined sample consists of only one compound.

- EXAMPLES -

The experiments were carried out in an argon atmosphere; THF was distilled over diethylmagnesium or magnesium anthracene · 3 THF (MgA).

The data of Examples 1 to 6 are shown in Table 1.

EXAMPLE 1

To a stirred solution/suspension of 6.94 g (16.6 mmoles) of MgA in 50 ml of THF there was dropwise added at room temperature (RT) within 1 hour a solution of 1.56 g (8.2 mmoles) of anhydrous SnCl_2 dissolved in 50 ml of THF, whereupon a black suspension formed. After stirring at RT for 1 hour, a 2 ml sample of the suspension was protolyzed with 2 ml of a mixture of toluene: CH_3OH , 25:1, (using $n\text{-C}_{16}\text{H}_{34}$ as internal standard) and analyzed by gas chromatography (GC), whereafter the batch contained 15.4 mmoles of anthracene and 0.3 mmoles of 9,10-dihydroanthracene. In the deep-blue THF solution, 9.4 mmoles of Mg^{2+} and 0.01 mmole of Sn were analyzed by complexometric analysis.

The suspension was filtered, and the solid was washed with THF until the washing liquid was colorless. After drying under vacuum (0.2 mbar), there were obtained 1.17 g of a black pyrophoric solid which had the composition Mg 12.4, Sn 60.5, C 1.9, H 0.3% (Mg:Sn = 1:1). After hydrolysis ($\text{H}_2\text{O} + 5\text{N H}_2\text{SO}_4$) of a sample of the solid and GC analysis of the organic portion, the solid contained 0.03% of anthracene. According to the X-ray powder analysis the solid was a mixture of the inter-metallic Mg compound Mg_2Sn with elemental Sn.

The preparation of the mixture of $\text{Mg}_2\text{Sn}^* + \text{Sn}^*$ was repeated in the same manner and with the same amounts as described above and was confirmed by X-ray powder analysis of an isolated small sample of the solid. The still moist solid left after filtration was suspended in 50 ml of THF, the stirred suspension was admixed with a solution of 8.2 mmoles of SnCl_2 in 47 ml of THF, and the mixture was stirred at RT for 7 hours. The suspension was filtered, the solid was washed with THF and dried under vacuum (0.2 mbar). According to the X-ray powder analysis, only Sn, but no Mg_2Sn , is present in the solid.

EXAMPLE 1a

(COMPARATIVE EXAMPLE TO EXAMPLE 1)

To a cooled and stirred solution or suspension of 6.45 g (15.4 mmoles) of MgA in 50 ml of THF there was added all at once a solution of 3.20 g (16.9 mmoles) of anhydrous SnCl_2 in 50 ml of THF; thereupon the temperature of the reaction mixture rose from 13 °C to 25 °C, and a black solid precipitated. During the subsequent stirring of the batch at RT, samples (of 2 ml) of the solution were taken, and by complexometric titration it was determined that the deposition of tin was completed already after about 3 minutes. After this time, upon the hydrolysis of the sample, a molar ratio of anthracene:9,10-dihydroanthracene of 30:1 was determined. The suspension was filtered, the precipitate was washed twice with 30 ml of THF each and dried under vacuum (0.2 mbar). 1.34 g of a black powder were obtained which had the composition of Sn 96.8, Mg 1.2, Cl 0.4% and a specific surface area of 16.2 m²/g.

EXAMPLE 2

The experiment was carried out and worked up in the same manner as in Example 1 while, however, the SnCl_2 solution was added all at once to the MgA suspension. After a period of reaction of 18 hours at RT, 29.0 mmoles of Mg^{2+} and only traces of Sn^{2+} were detected in the solution.

EXAMPLE 3

A. Preparation of Mg_2Sn from SnCl_2 and MgA:

To a stirred solution or suspension of 14.8 g (35.3 mmoles) of MgA in 100 ml of THF there was added at -60°C a solution of 1.69 g (8.9 mmoles) of SnCl_2 in 50 ml of THF. The resulting black suspension was allowed to warm up from -60°C to -30°C within 12 hours, from -30°C to RT within 12 hours, and was stirred at RT for further 12 hours. The suspension was filtered, and the solid was washed seven times with a total of 330 ml of THF, until the initially blue washing liquid running off was colorless. After drying under vacuum (0.2 mbar) there were obtained 1.65 g of a black pyrophoric powder having the composition of Mg 25.59, Sn 64.14, C 5.44, Cl 1.27, H 0.97%. According to the X-ray powder analysis the powder was amorphous; it had a specific surface area of $109.4\text{ m}^2/\text{g}$. This Mg_2Sn failed to give any reflections in the X-ray powder diagram even when tempered at 250°C for 4 hours.

B. Preparation of Mg_2Sn from SnCl_2 and MgA, followed by the reaction with CuCl_2 to form a Cu-Sn alloy:

To a stirred solution or suspension of 19.0 g (45.4 mmoles) of MgA in 150 ml of THF there was added at

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-78 °C a solution of 13.1 mmoles of SnCl_2 in 70 ml of THF; the resulting black suspension was allowed to warm up to RT within 6 hours, and was then stirred at RT for 4 days (cf. the preparation of Mg_2Sn^* described in A.). Once the Mg_2Sn^* had settled, the yellow supernatant solution was siphoned off, 50 ml of THF were added to the Mg_2Sn^* , the resulting suspension was stirred for 30 minutes, and the solution again was siphoned off. This operation was repeated two more times. Then Mg_2Sn^* was suspended in 100 ml of fresh THF, the suspension was admixed with 3.48 g (25.4 mmoles) of anhydrous CuCl_2 and was stirred at RT for 82 hours. The black suspension was filtered, the solid was washed 4 or 5 times with THF and was dried under high vacuum. Obtained were 3.18 g of a Mg-containing Cu-Sn alloy which had the composition set forth in Table 5. In the filtrate of the batch, there were found 20.6 mmoles of Mg^{2+} by way of an analysis. In addition to weak reflections caused by Sn, the alloy showed numerous reflections in the X-ray powder diagram which could not yet be assigned.

EXAMPLE 4

SnCl_2 was added as a solid material to the suspension of MgA in 170 ml of toluene. After 4 hours of stirring, 28 mmoles of anthracene and 0.4 mmoles of 9,10-dihydroanthracene were found to be present in the solution. Prior to the filtration, the mixture was stirred another 18 hours at RT and 2 hours at 50 °C.

EXAMPLE 7

A stirred suspension of 16.70 g (40.0 mmoles) of MgA in 100 ml of THF was admixed at -70 °C with a

solution of 43.3 moles of SnCl_2 in 176 ml of THF; the mixture, while stirred, was allowed to warm up to RT within 6 hours, and was then stirred for 66 hours at room temperature. A sample of the solid (0.94 g) was isolated and identified as elemental Sn by X-ray powder analysis and elemental analysis (Sn 97.85, Mg 0.57, C 0.44, H 0.11, Cl 0.74%). The clear supernatant solution was siphoned off from the remaining batch, 200 ml of THF were added to the Sn^* , the suspension was stirred for 10 minutes, and the solution was again siphoned off. This operation was repeated two more times. Sn^* was then suspended in 200 ml of fresh THF, 21.5 g (51.7 mmoles) of solid MgA were added to the suspension, and the mixture was stirred at RT for 1 h. The black suspension was filtered, the solid was washed with THF and dried under vacuum (0.2 mbar). Obtained were 4.29 g of Mg_2Sn^* (in admixture with little Sn^*), which was identified by means of an X-ray powder analysis; elemental analysis: Sn 72.49, Mg 20.78, Cl 0.59, C 2.82, H 0.43%.

EXAMPLE 8

A solution cooled at 0 °C of 16.2 mmoles of SnCl_2 in 87 ml THF was added to 5.72 g (14.8 mmoles) of MgA, and the black suspension was stirred at RT for 21 hours (cf. Example 1a). The supernatant solution was siphoned off; 60 ml of THF were added to the Sn^* , the resulting suspension was stirred for 30 minutes, and the solution was again siphoned off. A small portion of Sn^* (about 50 mg) were dried under vacuum and analyzed: Sn 92.86, Mg 0.22, C 0.74, H 0.16%; in the X-ray powder diagram, the Sn^* sample is identical with an authentic sample of Sn powder. The remainder of Sn^* was suspended in 10 ml

of THF and added to a mixture comprising 0.62 g (25.7 mmol) of Mg powder (270 mesh), 0.25 g (1.4 mmol) of anthracene, and 16 ml of a 0.53 molar MgCl_2 solution in THF (8.5 mmol of MgCl_2), which mixture in advance had been stirred at RT for 3 hours to form the deep-blue complex $[\text{Mg}_2\text{Cl}_3 \cdot 6 \text{ THF}]^{\oplus-}$ anthracene $^{\oplus}$. After 17 hours of stirring, the suspension was gray-violet, and the solution was deep-blue in color. The suspension was filtered, Mg_2Sn^* was washed 3 or 4 times with THF and was dried under vacuum (0.2 mbar). Obtained were 1.75 g of Mg_2Sn^* as a black powder of the composition Sn 71.91, Mg 25.82, Cl 0.39, C 1.26, H 0.23%. The X-ray powder diagram of the Mg_2Sn^* thus prepared conforms to that of the JCPDS data file (except for two low-intensity reflections). In the dark-blue tin-free filtrate there were found 1.04 mmol of anthracene and 0.14 mmol of 9,10-dihydroanthracene by GC analysis.

The data relating to the Examples 9 to 16 are shown in the Tables 2, 2a and 5.

EXAMPLE 9

A suspension of 1.11 g of MgH_2 (76.5% according to thermovolumetric analysis; 32.2 mmol of MgH_2), prepared by catalytic hydrogenation of magnesium [Cr catalyst, RT; Angew. Chem. 92 (1980) 845] in 60 ml of THF was stirred at RT and portionwise admixed with 2.89 g (16.3 mmol) of anhydrous PdCl_2 , and the resulting suspension was stirred at RT for 24 hours, whereupon 0.67 H_2/Pd were released. Upon heating the suspension at 60 °C for 6 hours until the H_2 evolution ceased, the amount of hydrogen evolved increased to 0.92 H_2/Pd . The suspension was filtered while still warm, and the solid

was subsequently washed with THF. After drying in vacuum (0.2 mbar), 2.10 g of an X-ray amorphous solid were obtained which had the composition of Pd 73.74, Mg 19.07, C 3.19, H 1.86, Cl 2.21%

($\text{Mg}_{1.13}\text{PdC}_{0.38}\text{H}_{2.66}\text{Cl}_{0.09}$). In the filtrate of the batch there were titrimetrically determined 17.0 mmoles of Mg^{2+} and 29.5 mmoles of Cl^- .

A sample of 1.59 g of the solid was heated from RT to 400 °C at a rate of 1 °C/min; in the course thereof, in the temperature range around 317 °C, corresponding to the decomposition temperature of MgH_2 , 224 ml of a gas (20 °C/1 bar) were obtained which had the composition of H_2 95.1, CH_4 1.2, C_4H_{10} 3.7%. After hydrogenation under pressure (20 bar/200 °C/24 hours), the sample was once more subjected to thermolysis as described above, whereupon only 26 ml of gas were formed. After this operation, the sample failed to absorb any H_2 in a hydrogen atmosphere at 102 °C under normal pressure, according to which finding the presence of finely divided metallic palladium is to be excluded. Due to the broad reflections at $d = 2.230$ (100), 3.161 (38.9), 1.822 (25.7), and 1.289 (25.0) in the X-ray powder diagram, the sample contains the cubic MgPd known from the literature (P.I. Kripyakevich, E.I. Gladyshevskii, *Kristallografiya* 5 (1960) 552; CA 13641, 1962), however not any free Mg or Pd. [After annealing a small portion of the sample (690 °C/72 hours/argon), the cubic MgPd was converted into the tetragonal $\text{Mg}_{0.9}\text{Pd}_{1.1}$ (X-ray powder reflections at $d = 2.2550$ (100), 2.1395 (34.2), 3.0264 (25.6), and 1.2555 (23.9))]. Upon a renewed pressure hydrogenation, the sample failed to yield virtually any gas as described above and exhibited the reflections of the tetragonal $\text{Mg}_{0.9}\text{Pd}_{1.1}$ in the X-ray

powder diagram, but no reflections of free Mg or Pd. Composition of the sample after the operations described: Pd 78.65, Mg 17.61, C 1.18, H 0.78, Cl 1.58% ($\text{MgPd}_{1.02}\text{C}_{0.14}\text{H}_{1.07}\text{Cl}_{0.06}$).

EXAMPLE 11

38 ml of a 1.31-molar MgH_2' -solution in THF (49.9 mmoles of MgH_2'), prepared according to the DE-OS 37 22 993 (catalyst: 1% by mole of FeCl_2 -Mg-anthracene, 4% by mole of quinuclidine, 9% by mole of MgCl_2) were stirred and at -78°C portionwise admixed with 2.57 g (14.5 mmoles) of anhydrous PdCl_2 . Then the batch with continuous stirring was allowed to warm up from -78°C to RT within 3 hours, whereupon the evolution of H_2 began to occur at about -55°C . The batch was stirred for further 42 hours at room temperature until the H_2 evolution ceased. Work-up and analysis were carried out as described in Example 9. Data on the experiment are shown in the Tables 2 and 2a. The resulting solid is the amorphous Mg-Pd carbide which is preparable also from MgH_2' and bis(η^3 -allyl)palladium (Zeitschr. Phys. Chem. N.F. 162 (1989) 191).

EXAMPLE 11a

COMPARATIVE EXAMPLE TO EXAMPLE 11

If MgH_2' is reacted with PdCl_2 in a molar ratio of 1:1 in THF at room temperature, then after work-up there is obtained a finely divided, highly reactive Pd powder (Table 2), however not any Mg-Pd compound.

EXAMPLE 12

59 ml of a 0.84-molar MgH_2 '-solution in THF (49.6 mmoles), prepared according to the DE-OS 37 22 993 were vigorously stirred and in a closed system at RT were portionwise admixed with 2.11 g (11.9 mmoles) of anhydrous PdCl_2 , so that the internal temperature did not exceed 30 °C. The H_2 evolution began immediately. After 1 hour of stirring at RT and development of altogether 1.13 H_2/Pd (Gl. 17) the suspension was filtered. Work-up and analysis were carried out as described in Example 9. Data on the experiment are shown in the Tables 2 and 2a. The resulting solid is the reversible hydride Mg_2PdH_x (literature quoted in Example 11), as is concluded from the behavior in dehydrogenation/re-hydrogenation cycles and from the composition.

EXAMPLE 13

To a stirred suspension of 2.48 g (14.0 mmoles) of the anhydrous PdCl_2 , dried under high vacuum, in 60 ml of THF at -78 °C there was added a solution cooled at -78 °C of 2.34 g (28.5 mmoles) of MgEt_2 in 50 ml of THF (the color turns to black!), and the suspension was subsequently stirred at the constant temperature for 48 hours. Then the vessel was connected to a gas burette, was then allowed with permanent stirring to warm up from -78 °C to RT within 2 hours and was then stirred at room temperature for another 48 hours. Then the volatile components were condensed under vacuum (0.2 mbar) in two cold traps connected in series (-78 °C and -196 °C). MS analysis of the quantities of the gases evolved during the warm-up period and at RT and present in the condensates yielded 2.02 $\text{C}_2\text{H}_6/\text{Pd}$ and

1.77 $\text{C}_2\text{H}_4/\text{Pd}$. The residue was taken up with 100 ml of fresh THF, the suspension was stirred at RT for a short time, filtered, the precipitate was washed several times with THF and twice with pentane, and was dried under high vacuum. 0.25 g of a black powder are obtained, which has the composition as reported in Table 2. In the THF solution having a deep-brown color there were found by complexometric titration after hydrolytic work-up 28.8 mmoles of Mg^{2+} , 28.6 mmoles of Cl^- and by atomic absorption analysis 12.3 mmoles of Pd^{2+} .

To an aliquot of the $\text{Pd}(\text{MgCl})_2$ solution prepared as described above (1.32 mmoles of Pd in 56 ml of THF) there were added 0.29 g (1.65 mmoles) of PdCl_2 , the suspension was stirred at RT for several days, centrifuged, and the resulting solid was washed with THF and dried under high vacuum. Obtained were 0.16 g of a solid, the composition of which has been set forth in Table 5.

Another part of the $\text{Pd}(\text{MgCl})_2$ solution (4.51 mmoles of Pd in 80 ml of THF) was admixed with the equimolar amount of SnCl_2 in THF (0.85 g, 4.50 mmoles of SnCl_2 in 10 ml of THF); the suspension was stirred at RT for 3 to 4 days, filtered, and the black, extremely fine precipitate was washed with THF. Upon drying under high vacuum there were obtained 1.02 g of an X-ray amorphous powder having the composition as indicated in Table 5. In the THF-filtrate of slightly brown color there were found by complexometric titration 8.8 mmoles of Mg^{2+} and 17.6 mmoles of Cl^- and by atomic absorption analysis 0.026 mmoles of Pd and 0.034 mmoles of Sn.

The data of the Examples 16 to 20 are shown in the Tables 3, 3a and 5, the data of the Examples 21 to 27 are shown in the Tables 4 and 5a, and the data of the Examples 28 to 32 are shown in the Tables 4a and 5a.

EXAMPLE 28

A suspension of 4.86 g (0.20 moles) of Mg powder (270 mesh) in 130 ml of tetrahydrofuran was subjected to an ultrasonic treatment for 1 3/4 hours; thereto, 2.53 g (19.9 mmoles) of FeCl_2 (anhydrous) were added, and the resulting mixture was again subjected to the ultrasonic treatment for 1 hour and then stirred at RT for 18 hours. An aliquot part of the suspension was centrifuged with 10,000 rpm for 1 hour to remove Mg and Fe^* from the solution. The determination of the amount of hydrogen evolved upon protolysis of an aliquot of the clear deep-blue solution and of the iron dissolved therein (13.5% of the initial FeCl_2 amount) resulted in 1.52 H_2/Fe .

EXAMPLE 32

A suspension of 20.0 g (0.82 moles) of Mg powder (270 mesh), 1.78 g (10 mmoles) of anthracene and 0.2 ml (2.6 mmoles) of ethyl bromide in 100 ml THF were stirred for 2 to 3 hours until the formation of MgA was completed. To the stirred product, 1.97 g (10.2 mmoles) of $\text{NiCl}_2 \cdot 0.9 \text{ THF}$ were added within two hours, the resulting mixture was stirred for 3 hours, filtered, and the filter cake was washed with THF. An aliquot of the clear black filtrate (113 ml) was hydrolyzed with 2N H_2SO_4 , and the hydrogen formed thereupon (2.2 H_2/Ni) was analyzed by mass spectrometry. A further sample of the

filtrate was protolyzed with CH_3OH which had been admixed with n-octane and n-hexadecane as internal standards; the sample was centrifuged (to remove the precipitated nickel), and the solution was analyzed by gas chromatography. The solution (113 ml) contained, according to the GC analysis, 1.0 mmole of n-butanol, 7.5 mmoles of 9,10-dihydroanthracene, 0.1 mmoles of anthracene, 0.2 mmoles of tetrahydroanthracene and 0.1 mmoles of 9-(4-hydroxybutyl)-9,10-dihydroanthracene and, according to the complexometric titration 6.6 mmoles of Ni^{2+} , 27.2 mmoles of Mg^{2+} and 17.0 mmoles of Cl^- .

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Example 33

13.0 g (31 mmoles) of MgA is suspended in 50 ml THF. 50 ml of a 0.45 molar solution of GaCl_3 in THF is dropped over a period of 0.5 h into the stirred MgA/THF suspension previously cooled to -78°C . The color of the suspension changes from orange to a dark brown-black. The suspension is allowed with stirring to warm up to room temperature over a period of ~ 18 h to give a black suspension. The product, active Ga metal (Ga^*), is allowed to settle on the bottom of the flask and the green or yellow colored supernatant is removed. The solid is washed with several additions of fresh THF until the supernatant is colorless. The metal can also be isolated by centrifuging the reaction slurry and, after washing, transferring the solid suspended in fresh THF to a Schlenk flask.

3.6 g (8.6 mmoles) of MgA are transferred at room temperature to the Ga^*/THF suspension via 4-shaped bridge. The reaction suspension immediately turns green. After stirring at room temperature for 24 h, the product is allowed to settle out of the suspension (now dark grey or black colored), washed with several additions of fresh THF, and dried under high vacuum. Yield: 90 % of Mg_2Ga_5 , obtained as a crystalline, black pyrophoric powder. Only the diffraction lines corresponding to Mg_2Ga_5 (Acta Cryst. B 25, (1969) 554) are noted in the X-ray diffraction pattern.

Example 34

9.21 g (22.3 mmoles) of MgA were suspended in 400 ml toluene and stirred at room temperature for 24 h yielding in a fine suspension of active magnesium (Mg^*). A large proportion of the solvent toluene was removed by decantation, leaving ca. 40 ml of toluene with Mg^* metal. After adding 100 ml of freshly distilled THF and 2.25 g (7.2 mmoles) of anhydrous BiCl_3 to Mg^*/THF suspension, the reaction suspension was stirred for 48 h at room temperature. After filtration, washing with THF and pentane, and drying under vacuum, 1.80 g (97 %) of Bi_2Mg_3 were obtained as a black pyrophoric powder having a specific surface area of $68\text{ m}^2/\text{g}$ and containing $\sim 4\text{ wt}\%$ of organic matter and $1.5\text{ wt}\%$ Cl. The X-ray powder diagram of Bi_2Mg_3 thus prepared exhibits, apart from two weak signals for Bi, only strong reflections for Bi_2Mg_3 .

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Examples 35-37

Anhydrous metal chlorides (AuCl_3 , HgCl_2 and PbCl_2 ; Table 6) were added in the course of 5 min to the stirred suspensions of MgA in THF and the reaction suspensions stirred for the time given in the table 6. After filtration, washing with THF (until the final wash was colorless) and drying under vacuum, the magnesium intermetallics (table 6) were obtained as black or grey powders and identified by X-ray powder diffractometry.

Example 38

NbCl_5 reacts with catalytically prepared magnesium hydride (US PS 4,554,153) in the molar ratio 1:5 in THF at room temperature with the evolution of 1.5 H_2/Nb and formation of a THF-soluble complex of the composition $\text{Cl}_2\text{Nb}(\text{HMgCl})_3$. After removing THF via vacuum distillation, the solid complex liberates upon thermolysis between 135 - 285 °C at ambient pressure gas with the composition H_2 69 % (0.8 H_2/Nb), 12 % CH_4 , 5 % C_2 -, 6 % C_3 - and 8 % C_4 -hydrocarbons.

Example 39

RhCl_3 reacts with MgEt_2 in the molar ratio 1:2 in THF at room temperature with evolution of 2.3 mole C_2H_6 - and 1.5 mole $\text{C}_2\text{H}_4/\text{Rh}$ and formation of a THF-soluble complex of the composition RhMg_2Cl_3 . The latter reacts with SnCl_2 in the molar ratio 2:1 in boiling THF with formation of a precipitate of a Rh-Sn-alloy Rh_2Sn .

Example 40

In the course of the reaction of IrCl_3 with MgEt_2 in the molar ratio of 1:3 in THF at room temperature, 2.3 moles C_2H_6 , 1.2 mole C_2H_4 and 0.3 mole $\text{C}_2\text{H}_2/\text{Ir}$ are set free, while 1 mole of MgEt_2 remains unchanged. The clear THF solution contains an Ir-complex of the composition IrMg_2Cl_3 analogous to the complex RhMg_2Cl_3 of the example 39.

Example 41

To a suspension of 1.06 g (34.1 mmoles) of catalytically prepared magnesium hydride (MgH_2^* , US PS 4,554,153) in 30 ml THF were added 1.58 g (7.5 mmoles) of anhydrous RhCl_3 and the suspension stirred for 22 h at room temperature resulting in the evolution of 1.2 mole H_2/Rh . The precipitate was filtered off, washed with THF and dried in high vacuum affording 1.53 g of a solid. 1.14 g of the solid delivered on programmed heating (1 °C/min) to 400 °C at ambient pressure 291 ml gas composed of CH_4 and H_2 (62.9 %). The resulting solid was subjected to two hydrogenation/dehydrogenation cycles (1. cycle: hydrogenation at 30–40 bar H_2 /230–380 °C/71 h; dehydrogenation at ambient pressure r.t. – 400 °C, 1 °C/min, 118 ml H_2 . 2. cycle: hydrogenation at 25 bar H_2 /200 °C/24 h; dehydrogenation as in the first cycle, 98 ml of a 10:1 H_2 – CH_4 mixture) and thereafter annealed under argon at 550 °C for 20 h. The X-ray powder diffraction lines of the annealed sample can be assigned to a hitherto unknown intermetallic Mg_2Rh having a tetragonal ($a = 3.1914$, $b = 10.1054$ Å) MoSi_2 structure type.

TABLE 1: Preparation of the intermetallic compound Mg_2Sn or of the finely divided tin from $SnCl_2$ and magnesium anthracene $\cdot 3$ THF (MgA), Mg in the presence of anthracene or Mg

Ex- ample No.	$SnCl_2$ g (mmoles)	Mg- Component g (mmoles)	Sn:Mg Atomic Ratio	Solvent [ml]	React.Temp. [°C]/React. Time[h] ^{a)}	Solid Material [g]	Composition [%]			Surface area ^{b)} [m ² /g]	X-ray Powder Analysis	Procedure and Work-up
							Mg	Sn	C H Cl			
1	1.56 (8.2)	MgA 6.94 (16.6)	1:2	THF 100	RT/1	1.17	12.4	60.5	1.9 0.3		Mg_2Sn+Sn	cf. Text Example 1
1a	3.20 (16.9)	MgA 6.45 (15.4)	1:1	THF 100	RT/1	1.34	1.2	96.8	0.4	16.2	cf.	cf. Text
2	5.14 (27.1)	MgA 34.8 (83.1)	1:3	THF 445 ^{c)}	RT/18	4.98	23.3	69.8	4.4 1.6 0.1	36.4	Example 8	Example 1a
3	1.69 (8.9)	MgA 14.8 (35.3)	1:4	THF 150 ^{c)}	-60-30/16 -30 RT/12 RT/12	1.65	$Mg_{1.63} Sn$ 25.6 64.1 5.4 1.0 1.3 $Mg_{1.94} Sn$			109.4	$Mg_2Sn +$ little Sn	Same as Example 1
4	1.76 (9.3)	MgA 11.5 (27.5)	1:3	Tol. 170	RT/22 50/2	1.61 ^{e)}	22.7	66.0	4.9 0.8 3.0	76	$Mg_2Sn +$ traces of Sn	cf. Text Example 4
5	1.23 (6.5)	Mg ^{d)} 0.45 (18.5)	1:3	THF 100 ^{c)}	RT/18	0.97 ^{e)}	25.9	72.7	0.4 0.2 0.4	14.8	$Mg_2Sn +$ little Sn	Same as Example 1
6	1.10 (5.8)	Mg ^{h)} 0.44 (18.1)	1:3.1	THF 65	RT/6	0.83 ⁱ⁾	26.4	71.9	0.6 0.2 0.5	10.2	$Mg_2Sn +$ little Sn	Same as Example 1

a) After completion of the addition of $SnCl_2$. - b) BET method. - c) $SnCl_2$ dissolved in 1/3 of the total amount of THF. - d) Also after 4 hours of annealing at 250 °C. - e) The solid was washed 2 times with toluene and 3 times with THF. - f) Mg powder (270 mesh + 3.3% by mole of MgA. - g) In solution 7.3 mmoles of Mg^{2+} and 0.0 mmoles of Sn. - h) Mg powder (270 mesh). - i) In solution 3.9 mmoles of Mg^{2+} and 0.0 mmoles of Sn.

TABLE 2: Preparation of intermetallic Mg-Pd compounds or of the hydrides thereof from PdCl₂ and catalytically prepared undissolved (MgH₂^{*}) or dissolved magnesium hydride (MgH₂¹) or organomagnesium compounds

Ex- ample No.	PdCl ₂ g (mmoles)	Mg- Component (mmoles)	Pd:Mg Ratio	THF [ml]	React.Temp. [°C]/React. Time[h] ^{a)}	Evolved Gas moles/ g-atom of Pd	Solid Material [g]	Composition[%] Mg Pd C H Cl	X-ray Powder in soln./mole Analysis of PdCl ₂ used	Procedure and Work-up
9	2.89 (16.3)	MgH ₂ [*] (32.2)	1:2	60	RT/24 60/6	0.92 H ₂	2.10 ^{e)}	19.1 73.7 3.2 1.9 2.2 Mg _{1.13} PdC _{0.38} H _{2.66} Cl _{0.1}	am. 1.04:1.81	cf. Text Example 9 ^{c)}
10	3.29 (18.5)	MgH ₂ [*] (56.2)	1:3	60	RT/2 b.p./4.5	1.1 H ₂	2.80 ^{e)}	29.9 65.3 2.0 2.2 0.7 Mg ₂ PdC _{0.27} H _{3.49} Cl _{0.03}	am. 1.17:2.00	Same as Example 9 ^{c)}
11	2.57 (14.5)	MgH ₂ [*] (49.9)	1:3.4	38	-78 RT/3 RT/42	1.6 H ₂	1.94 ^{e)}	17.4 77.3 3.7 1.2 0.5 MgPdC _{0.43} H _{1.6} Cl _{0.02}	am. 2.39:2.2:1.2	cf. Text Example 11 ^{c)}
11a ^{d)}	2.74 (15.4)	MgH ₂ [*] (15.7)	1:1	31	RT/3	0.64 H ₂	1.59 ^{e)}	0.4 95.6 1.8 1.2 0.7	Pd 1.19:2.1	Same as Example 11
12	2.11 (11.9)	MgH ₂ [*] (49.6)	1:4	59	RT/1	1.13 H ₂	1.75 ^{e)}	29.1 63.8 3.9 2.7 0.3 Mg ₂ PdC _{0.54} H _{4.45} Cl _{0.01}	am. 0.08:2.31:2.4:1.28	cf. Text Example 12 ^{c)}
13	2.48 (14.0)	MgEt ₂ (28.5)	1:2	110	-78/48 -78 RT/2 RT/48	2.02 C ₂ H ₆ 1.77 C ₂ H ₄	0.25	12.1 61.4 6.7 1.1 4.2 MgPd _{1.16} C _{1.12} H _{2.17} Cl _{0.2}	0.88:2.06:2.05	cf. Text Example 13 ^{f)}
13a ^{d)}	1.15 (6.5)	MgEt ₂ (6.5)	1:1	50	-78/2.5 -78 RT/2 RT/12	1.5 C ₂ H ₆ 0.6 C ₂ H ₄	0.68	0.5 92.9 3.2 0.3 2.7	g) 0.93:1.7	Same as Example 13
14	2.12 (12.0)	EtMgBr (47.8)	1:4	141	-78/12 -78 RT/20 RT/16	1.9 C ₂ H ₆ 1.7 C ₂ H ₄	0.21	10.3 80.4 4.9 1.1 3.2 MgPd _{1.8} C _{1.0}	3.9:6.2 ^{h)}	Same as Example 13 ⁱ⁾
15	1.77 (10.0)	EtMgBr (99.5)	1:10	200	-78/11 -78 RT/16 RT/17	1.9 C ₂ H ₆ 1.6 C ₂ H ₄	0.0		9.9:11.8 ^{h)}	Same as Example 13 ⁱ⁾

a) After completion of the addition of PdCl₂.

b) Due to the hydrogen developed upon protolysis.

c) Thermal treatment and/or dehydrogenation of Table 2a.

d) Comparative experiments.

e) The solid reversibly reacts with 0.6-0.7 H₂/Pd (Absorption: RT to +80 °C; Desorption: 150 °C/normal pressure.

f) Reaction with PdCl₂ and SnCl₂ cf. Table 5.

g) Diffuse reflections; after annealing (600 °C, 72 hours): Pd.

h) Sum of Cl + Br.

i) However, solid PdCl₂ was added to the EtMgBr solution.

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TABLE 2a: Dehydrogenation/Re-hydrogenation of the ternary Mg-Pd hydrides and thermal treatment of the inter-metallic Mg-Pd compounds from the Examples 9 to 12 and results of the X-ray powder analysis

Ex- ample No.	1 st Dehydrogen. ml of gas ^{b)}	Temp. range[°C]	or thermal treatm. ^{a)}	Re-hydro- generation	2 nd Dehyd./therm.treatm. ^{a)}	X-ray Powder Analysis	3 rd Dehydr. ml of H ₂ ^{b)}	Temp. range[°C]	Empirical Formula after the 3 rd Dehydr. /Thermal Treatment
9	141	317	95.1 1.2 3.7	20/200/24	16	MgPd ^{d)} 95/160/24	max. 8		MgPdC _{0.14} H _{1.07} Cl _{0.06}
10	241	323	96.9 - 3.1	20/200/24	48	diffuse ^{f)} 20/200/89	56	255 ^{g)}	diffuse
11	46	100-280	93.2 - 3.2	15/200/24	0 ^{h)}	amorphous			
12	179	252	94.2 - 5.8	15/200/24	65	245 100	50	243 ^{g)}	Mg ₂ PdC _{0.07} H _{0.54} Cl _{0.07}

a) A sample of 1-2 g of the solid is heated in the thermo-volumetric apparatus (Chem.-Ing.-Techn. 55 [1983] 156) at a heating rate of 1 °C/min from room temperature up to 400 °C. - b) ml of gas (20 °C/1 bar) per gram of weighed sample. - c) According to the MS analysis. - d) A small part of the sample was annealed at 690 °C for 72 hours; thereupon, reflections of the tetragonal Mg_{0.9}Pd_{1.1} were observed in the X-ray powder diagram. - e) Composition after the second dehydrogenation: Mg₂PdC_{0.07}H_{0.88}Cl_{0.02}. - f) A small part of the sample was annealed at 600 °C for 48 hours; thereupon, sharp reflections of the cubic MgPd were observed in the X-ray powder diagram. - g) Corresponding to the decomposition temperature of the Mg₂PdH_x (Zeitschr. Phys. Chem. H.F. 162 (1989) 191). - h) Composition after the second thermal treatment MgPdC_{0.03}H_{0.12}Cl_{0.15}.

TABLE 3: Preparation of intermetallic Mg-Pt compounds or of the hydrides thereof from PtCl_2 and catalytically prepared undissolved (MgH_2^*) or dissolved magnesium hydride (MgH_2') or magnesium diethyl

Ex-ample No.	PtCl_2 g (mmoles)	Mg-Component g (mmoles)	Pt:Mg Atomic Ratio	THF [ml]	React. Temp. [°C]	Time[h] ^{a)}	Evolved Gas moles/g-atom of Pt	Solid [g]	Material	Composition[%] Mg Pt C H Cl	X-ray Analysis mole of PtCl_2	Procedure
16	5.63 (21.2)	MgH_2^* (42.5)	1:2	50	RT/65 ^{e)}		0.97 H_2	4.74 ^{d)}		10.3 85.7 1.6 1.0 1.1	e)	Same as Example 9 ^{d)}
17	1.93 (7.2)	MgH_2^* (21.7)	1:3	40	RT/21		1.07 H_2	1.80 ^{d)}		$\text{MgPt}_{1.04}\text{C}_{0.32}\text{H}_{2.41}\text{Cl}_{0.07}$ 20.4 71.8 3.7 2.6 1.4	e)	Same as Example 9 ^{d)}
18	2.68 (10.1)	MgH_2^* (30.3)	1:3	30	-78/11 -78 RT/6		1.34 H_2	2.40 ^{d)}		$\text{Mg}_{2.28}\text{PtC}_{0.84}\text{H}_{6.96}\text{Cl}_{0.1}$ 11.1 81.1 3.3 1.3 3.1	am.	Same as Example 11 ^{d)}
19	2.85 (10.7)	MgH_2' (42.8)	1:4	49	RT/1		1.03 H_2	2.50 ^{d)}		$\text{Mg}_{1.1}\text{PtC}_{0.65}\text{H}_{2.98}\text{Cl}_{0.2}$ 21.0 71.4 4.4 1.6 1.5	am.	Same as Example 12 ^{d)}
20	4.24 (15.9)	MgEt_2 (31.8)	1:2	115	-78 RT/1 b.p./0.5		2.0 C_2H_6 1.8 C_2H_4	0.0		$\text{Mg}_{2.36}\text{PtC}_{1.01}\text{H}_{4.2}\text{Cl}_{0.1}$ 1.0:2.0:1.9		Same as Example 13

a) After completion of the addition of PtCl_2 . - b) Due to the hydrogen developed upon protolysis. - c) After 1 hour 0.90 H_2 /Pt. - d) Thermal treatment and/or dehydrogenation cf. Table 3a. - e) Diffuse reflections.

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TABLE 3a: Dehydrogenation of the ternary Mg-Pt hydrides and thermal treatment of the intermetallic Mg-Pt compounds from the Examples 16 to 19 and results of the X-ray powder analysis

No.	Ex- 1 st Dehydrogen. or thermal treatm. ^{a)}			Hydrogen. 2 nd De- Cond. hydr. ^{a)}	Composition [%] Mg Pt C H Cl	X-ray Powder Analysis	Annealing of the Sample °C/hour	X-ray Powder Analysis after Annealing
	Temp. range[°C]	Gas Composition ^{c)}	ml of gas ^{b)}					
		CH ₄ C ₃ H ₈ C ₄ H ₁₀	bar/°C/h					
16	90	357 86.5 5.1 2.5	1.5	40/240/24	0	10.1 88.5 0.3 0.2 0.8	700/24	MgPt ₃ ^{d)}
17	156	340 89.3 4.7 2.1	3.8	40/240/24	0	MgPt _{1.09} C _{0.06} H _{0.4} Cl _{0.05}	700/24	e)
						20.7 76.6 0.5 0.3 1.8		
18	66	88-300 86.7 4.8 -	8.5	50/200/48	0	Mg _{2.17} PtC _{0.1} H _{0.66} Cl _{0.13}	600/24	tetragonal MgPt ₃ ^{d)}
						14.4 0.3 0.1 2.9		
19	117	210-375 83.4 3.6 -	12.4	100/200/60	22 ^{e)}	19.3 78.6 0.4 0.3 1.5	700/24	e)
						Mg ₂ PtC _{0.09} H _{0.41} Cl _{0.11}		

a), b), c) cf. Table 2a. - d) The sample additionally contains still one (?) further Mg-Pt phase. - e) Monoclinic Mg₂Pt and tetragonal MgPt (cf. Figure 1). - f) cf. Figure 2. - g) At about 320 °C (98% of H₂) corresponding to MgH₂.

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TABLE 4: Preparation of THF-soluble M^1 -Mg hydridehalides or of intermetallic Mg compounds from metal halides (M^1Cl_m) and dissolved magnesium hydride (MgH_2)^{a)}

Ex-ample No.	M^1Cl_m g (mmoles)	MgH_2 [mmoles]	$M^1:Mg$ Atomic Ratio	THF [ml]	React.Temp. [°C]/React. Time[h] ^{a)}	H ₂ -Evolution [moles/g-atom of M^1]	Solid Material [g]	$M^1:Mg:Cl:H$ ^{b)} in soln./mole of M^1Cl_m	Procedure and Work-up
21	FeCl ₂ 4.20 (33.1)	71.8	1:2.2	50	-78 RT/5 RT/3	0.92	0.0	1.0:2.03:2.35:2.26	Same as Example 11 ^{c)}
21a	FeCl ₂ 1.84 (14.5)	14.7	1:1	29	-78 RT/5 RT/3	0.79	0.92 ^{d)}	0.02:1.0:2.0	Same as Example 11
21b	FeCl ₂ 3.83 (30.2)	45.4	1:1.5	62	-78 RT/15 RT/3	0.89	1.20	0.45:1.39:2.26:0.59	Same as Example 11
22	CoCl ₂ 6.45 (49.7)	103	1:2	53	-78 RT/5 RT/3	0.99	0.57 ^{e)}	1.0:2.18:2.43:1.96	Same as Example 11 ^{f)}
23	NiCl ₂ ·1.5 THF 4.05 (17.2)	35.1	1:2	29	-78/26 -78 RT/24 RT/18	1.0	g)	1.0:2.07:2.13:2.07	Same as Example 11 ^{h)}
23a	NiCl ₂ ·1.5 THF 4.05 (17.2)	18.0	1:1.06	25	-78 RT/17	0.80	1.02 ⁱ⁾	0.06:1.05:2.03:0.12	Same as Example 11
24	RuCl ₃ 1.03 (5.0)	15.1	1:3	20	-78 RT/25 RT/22	0.75	-	-	Same as Example 11
25	RhCl ₃ 1.21 (58)	18.7	1:3.2	26	+25+30/2	1.4	0.068	-	Same as Example 11
26	MnCl ₂ 1.72 (13.7)	54.6	1:4	38	+20+30/4	1.1	0.037	-	Same as Example 11
27	CuCl ₂ 6.38 (46.8)	97.0	1:2.07	60	-	1.2	4.25	-	Same as Example 11

a) After completion of the addition of M^1Cl_m . - b) Due to the hydrogen developed upon protolysis. - c) Reaction with FeCl₂, CoCl₂, NiCl₂ and CuCl₂; cf. Table 5a. - d) Fe 86.4, Mg 1.6, C 6.0, Cl 6.2% - e) Substantially MgH₂, according to the elemental analysis. - f) Reaction with FeCl₂, cf. Table 5a. - g) Small amount of MgCl₂. - h) Reaction with NiCl₂ and CoCl₂, cf. Table 5a. - i) Ni 87.7, Mg 2.0, C 6.8, H 1.4, Cl 2.1%.

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TABLE 4a: Preparation of THF-soluble complexes $\text{Fe}_2\text{Mg}_3\text{Cl}_4$, $\text{Ni}_2\text{Mg}_3\text{Cl}_4$ and $\text{Ni}(\text{MgCl})_2 \cdot \text{MgA}$ from FeCl_2 and NiCl_2 , respectively, and Mg powder, optionally in the presence of activators

Ex-ample No.	M^1X_m g (mmoles)	Mg Powder ^{a)} [mmoles]	$\text{M}^1\text{:Mg}$ Atomic Ratio	Activator (mmoles)	THF [ml]	Reaction Time at RT [hours]	M^1 [%] in Soln. ^{b)}	H_2/M^1 after Protolysis	Procedure and Work-up
28	FeCl_2 (19.9)	200	1:10	—	130	19	13.6	1.52	cf. Text Example 28
29	FeCl_2 (19.9)	200	1:10	Quinuclidine (26)	130	19	28.9	1.56	Same as Example 28
30	$\text{NiCl}_2 \cdot 1.5 \text{ THF}$ (27)	823	1:30	$(\text{CH}_2\text{Br})_2^{\text{c)}$	67		23.7	1.48	Same as Example 28 ^{d)}
31	$\text{NiCl}_2 \cdot 1.5 \text{ THF}$ (16.1)	411	1:25	—	100	5	33.0 ^{e)}	1.49	Same as Example 28
32	$\text{NiCl}_2 \cdot 0.9 \text{ THF}$ (10.2)	823	1:81	Anthracene (10)	100	3	64.7	2.2	cf. Text Example 32

a) 270 mesh.- b) After centrifugation of filtration. - c) 0.05 ml. - d) Reaction with FeCl_2 , cf. Table 5a. - e) Undissolved portion: 9.89 g (Hg 86.1, Ni 8.1, Cl 1.2%).

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TABLE 5: Preparation of finely divided metal powders or alloys¹ from Mg₂Sn, Pd(MgCl)₂ or Pt(MgCl)₂ and metal halides M¹Cl_m or M²Cl_n

Ex- ample No.	M ¹ Mg-Compon. (mmoles of M ¹)	M ¹ Mg in ml of THF	M ¹ Cl _m or M ² Cl _n (mmoles)	M ¹ :M ² Atomic Ratio	M ¹ :M ² React.Temp. [°C]/React. Time[h] ^{a)}	Solid Material [g]	Composition M ¹ M ² Mg C H Cl Empirical Formula	X-ray Powder Analysis	M ¹ :Mg:Cl:M ² in solution per mole of M ¹ used	Procedure and Work-up
1	Mg ₂ Sn+Sn (8.2)	97	SnCl ₂ (8.2)	1:1	RT/7			Sn		cf. Text Example 1
3 B	Mg ₂ Sn (13.1)	150	CuCl ₂ (25.9)	1:2	RT/82	3.18	47.6 41.5 2.4 3.6 0.5 1.9 Cu _{1.62} SnMg _{0.25}	b)	1.57	cf. Text Example 3B
13	Pd(MgCl) ₂ (1.32)	56	PdCl ₂ (1.65)		RT/3-4 days	0.16	89.1 0.04 3.9 2.7 4.1			cf. Text Example 13
13	Pd(MgCl) ₂ (4.51)	90	SnCl ₂ (4.50)	1:1	RT/3-4 days	1.02	43.5 42.8 2.0 5.9 1.0 4.6 Pd _{1.13} SnMg _{0.23} C _{1.36} H _{2.72} Cl _{0.36}	amorphous ^{c)}	1.94:3.90	cf. Text Example 13
20	Pt(MgCl) ₂ (6.15)	100	SnCl ₂ (5.65)	1.09:1	RT/48 h	2.03	59.6 33.7 1.1 3.5 0.7 0.7 Pt _{1.08} SnMg _{0.16} Cl _{2.52} Cl _{0.07}	PtSn ^{d)}	0.01:2.18:3.74:0.01	Same as Pd(MgCl) ₂ +SnCl ₂ in Example 13

a) After completion of the addition of M¹Cl_m or M²Cl_n. - b) Besides weak Sn reflections there are numerous reflections which have not yet been assigned. - c) Even after annealing at 800 °C for 24 hours. - d) Amorphous; crystalline only after annealing at 700 °C for 24 hours.

TABLE 5a: Preparation of finely divided metal powders or alloys from THF-soluble M¹-Mg (hydride)halides or halides Fe(HMgCl)₂, Co(HMgCl)₂, Ni(HMgCl)₂ and Ni₂Mg₃Cl₄ and metal halides (M¹Cl_m or M²Cl_n)

Ex- ample No.	M ¹ Mg-(hydride) halide (mmoles of M ¹)	THF [ml]	M ¹ Cl _m or M ² Cl _n (mmoles)	M ¹ :M ² Atomic Ratio	React.Temp. H ₂ /- [°C]/React. Time[h] ^{a)}	Solid Material [g]	Composition M ¹ M ² Mg C H Cl Empirical Formula	X-ray Powder Analysis mole of M ¹	M ¹ :Mg:Cl:M ² in solution per and Work-up	Procedure
21	Fe(HMgCl) ₂ (17.3)	81	FeCl ₂ (18.9)	0.92:1	-78 RT/5	0.84			Trace :2.2:4.2	b)
21	Fe(HMgCl) ₂ (60.4)	2676	CoCl ₂ (58.2)	1.04:1	RT/	0.98	31.8 32.0 3.1 9.5 1.7 12.1 Fe _{1.05} CoMg _{0.23} C...H _{0.16} Cl _{0.63}	FeCo	Trace:1.8:3.5:0.01	c)
21	Fe(HMgCl) ₂ (14.7)	40	NiCl ₂ (14.7)	1:1	-78/5 -78 RT/6	0.74	39.4 41.9 1.2 9.2 1.9 2.7 FeNiMg _{0.07} C _{1.07} H _{2.7} Cl _{0.1}		0.05:2.0:4.1:0.03	b)
21	Fe(HMgCl) ₂ (18.4)	100	CuCl ₂ (18.6)	1:1	RT/3 -78/5 -78 RT/6	0.93	35.0 46.0 0.9 7.9 1.1 3.8 Fe _{0.87} CuMg _{0.05} C _{0.91} H _{1.4} Cl _{0.15}		0.15:1.9:4.1:0.14	b)
22	Co(HMgCl) ₂ (40.6)	140	FeCl ₂ (44.8)	0.91:1	RT/3 -78 RT/	0.77		FeCo	0.01:2.0:3.9:0.0	b)
22a								FeCo		
23	Ni(HMgCl) ₂ (12.3)	47	NiCl ₂ ·1.5 THF (12.0)	1:1	-78 RT/20	0.45	77.8 3.6 3.3		0.1:2.0:4.0	b)
23	Ni(HMgCl) ₂ (11.6)	35	CoCl ₂ (10.8)	1.07:1	-78 RT/19	0.42	42.6 42.7 3.5 4.9 2.0 4.1 NiCoMg _{0.2} C _{0.56} H _{2.75} Cl _{0.16}	amorphous	0.01:2.1:4.2:0.11	b)
30	Ni ₂ Mg ₃ Cl ₄		FeCl ₂					FeNi ₂		

a) After completion of the addition of M¹Cl_m or M²Cl_n. b) In the same manner as Pd(MgCl)₂ + SnCl₂ in Example 14. c) In this case the solution of Fe(HMgCl)₂ in 176 ml of THF was dropwise added within 6.5 hours to the stirred solution of CoCl₂ in 2.5 liters of THF.

Table 6. Preparation of MgAu, MgHg and MgPb intermetallics from magnesium anthracene · 3 THF (MgA) and metal chlorides (MX_n) in THF

Ex- ample No.	MgA g (mmole)	MX _n g (mmole)	Mg:M ratio	THF [ml]	react. time [h]	isol. solid [g]	composition[%]					spec. surface [m ₂ /g]	X-ray diffr.
							Mg	M	C	H	Cl		
35	9.2 (23)	AuCl ₃ 1.65 (5.4)	4.2:1	70	22	1.20	13.8	67.7	11.1	1.5	1.5	73.4	MgAu ¹⁾
							Mg _{1.65} Au						
36	5.8 (14)	HgCl ₂ 1.06 (3.9)	3.7:1	40	120	0.82	12.1	75.8	6.0	0.6	0.1	12.1	MgHg
							Mg _{1.32} Hg						
37	6.8 (17)	PbCl ₂ 1.51 (5.4)	3.1:1	70	120	1.31	17.2	80.4	1.5	0.2	0.3	6.0	Mg ₂ Pb +Pb
							Mg _{1.83} Pb						

1) After heating the sample under argon to 400 °C for 24 h

CLAIMS:

1. Metal-magnesium compounds (M^1 -Mg-compounds), produced by the reaction of halides of the metals of the Groups IIIA-VA, VB-VIIB, VIII, IB and IIB of the Periodic Table (M^1X_m), or of metals M^1 or M^1 -hydrides, in an organic solvent with magnesium hydride (MgH_2), hydridemagnesium halides ($HMgX$), organomagnesium compounds and/or metallic magnesium.
2. The compounds according to claim 1, characterized in that the reaction is carried out in the presence of anthracene or its derivatives, magnesium anthracene . 3 THF (MgA) or its derivatives, magnesium halides, organic halides and/or quinuclidine as activators.
3. The compounds according to claim 1, characterized in that tetrahydrofuran (THF) is used as solvent.
4. The compounds according to claim 1, characterized in that metals M^1 or M^1 -hydrides are employed in a finely divided, highly reactive form.
5. The compounds according to claim 1, characterized in that the magnesium component has been dissolved or partially dissolved in the organic solvent.
6. The compounds according to claims 2 and 4, characterized in that an insoluble magnesium component is employed in the presence of the activators.
7. The compounds according to claim 1, characterized in that catalytically prepared (MgH_2^*) or catalytically prepared dissolved MgH_2 (MgH_2') is employed as the MgH_2 .

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8. The compounds according to claim 1, characterized in that as the preferred organomagnesium compounds there are employed C_1 - C_{12} -alkylmagnesium halides, di- C_1 - C_{12} -alkylmagnesium compounds, MgA or its derivatives and/or $Mg_2Cl_3(THF)_6^{\oplus}$ -anthracene $^{\ominus}$.
9. The compounds according to claim 1, characterized in that the reaction of M^1X_m with the Mg component is carried out in two steps, wherein first M^1X_m is reacted with the Mg component to form M^1 or the M^1 hydride, and then the resulting M^1 or M^1 hydride is subsequently reacted with a further amount of the Mg component in a solvent, or in the solid state by means of a subsequent thermal treatment, to form the M^1 -Mg compound.
10. The intermetallic compound Mg_2Sn , prepared from $SnCl_2$ and MgA in THF or toluene.
11. The intermetallic compound Mg_2Sn , prepared from $SnCl_2$ and Mg powder in THF.
12. The intermetallic compound Mg_2Sn , prepared from finely divided metallic Sn and MgA or Mg in the presence of anthracene and/or $MgCl_2$ in THF.
13. The cubic intermetallic compounds $MgPd$ and Mg_2Pd , prepared from $PdCl_2$ and MgH_2^* in THF and subsequent thermal treatment of the resulting Pd - MgH_2^* mixtures.
14. The amorphous 1:1 and 2:1 Mg-Pd hydrides, prepared from $PdCl_2$ and MgH_2 in THF, and the amorphous $MgPdC_x$ or cubic Mg_2Pd resulting from the thermal treatment thereof.

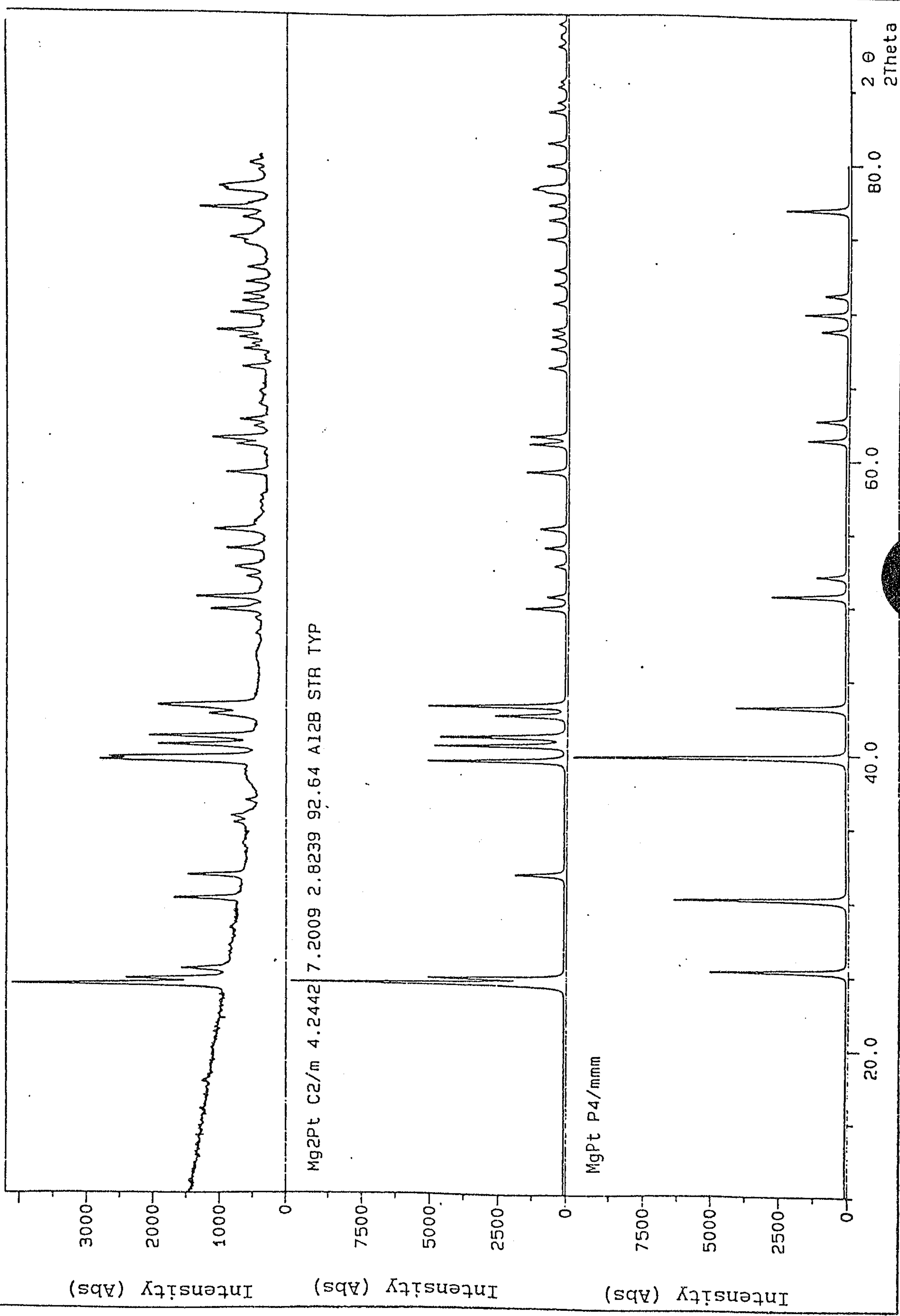
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15. The amorphous intermetallic compounds MgPt and Mg₂Pt, prepared from PtCl₂ and MgH₂^{*} in THF and subsequent thermal treatment of the resulting Pt-MgH₂ mixtures; the tetragonal MgPt₃ or the monoclinic Mg₂Pt in admixture with the tetragonal MgPt, prepared by annealing amorphous MgPt or Mg₂Pt.
16. The amorphous 1:1 and 2:1 Mg-Pt hydrides, prepared from PtCl₂ and MgH₂['] in THF, and the monoclinic Mg₂Pt and tetragonal MgPt resulting from the thermal treatment or annealing thereof.
17. The amorphous MgCu-hydride, prepared from CuCl₂ and MgH₂['] in THF, and the intermetallic Mg-Cu compounds resulting from the thermal treatment thereof.
18. The compounds THF-soluble Pd(MgCl)₂ and THF-soluble Pt(MgCl)₂, prepared from PdCl₂ and PtCl₂, respectively, and magnesium dialkyls or alkylmagnesium halides in THF.
19. The compounds THF-soluble Pd(MgCl)₂ and THF-soluble Pt(MgCl)₂.
20. The compounds THF-soluble Fe(HMgCl)₂, THF-soluble Co(HMgCl)₂, and THF-soluble Ni(HMgCl)₂, prepared from FeCl₂, CoCl₂ and NiCl₂, respectively, and MgH₂['] in THF.
21. The compounds THF-soluble Fe(HMgCl)₂, THF-soluble Co(HMgCl)₂, and THF-soluble Ni(HMgCl)₂.

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22. The THF-soluble Ru, Rh and Mn hydridemagnesium chlorides, prepared from RuCl_3 , RhCl_3 and MnCl_2 , respectively, and MgH_2 in THF.
23. The compounds THF-soluble $\text{Fe}_2\text{Mg}_3\text{Cl}_4$ and THF-soluble $\text{Ni}_2\text{Mg}_3\text{Cl}_4$, prepared from FeCl_2 and NiCl_2 , respectively, and Mg powder,
24. The compounds THF-soluble $\text{Fe}_2\text{Mg}_3\text{Cl}_4$ and THF-soluble $\text{Ni}_2\text{Mg}_3\text{Cl}_4$.
25. The compound THF-soluble $\text{Ni}(\text{MgCl})_2 \cdot \text{MgA}$, prepared from NiCl_2 and Mg powder in the presence of MgA.
26. Use of the $\text{M}^1\text{-Mg}$ compounds according to claims 1 to 25 for the preparation of finely divided metal and alloy powders and of intermetallic compounds by reacting same with metal or element halides.
27. Use according to claim 26, characterized in that the reaction of $\text{M}^1\text{-Mg}$ compounds is carried out in a solvent.

Figure 1



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Figure 2

