Presentation of a research project
and call for its funding:

Searching for
Room Temperature Superconductors

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The interesting and fascinating physical phenomenon of superconductivity appears, until now, only at very low temperatures and therefore its technical application is limited to relatively few areas. If it is possible to create materials which are superconducting at room temperature, then this could initiate a revolution in technology. More than 10 years fundamental research, experience, knowledge and ideas in the field of special materials (oxides) lead to the conviction that superconductivity at room temperature is possible, and together with Global Scaling – a new knowledge and holistic approach in science – to an extended approach on the search for room temperature superconductors.

This presentation is divided into a main part (28 pages) and an appendix (38 pages). A content overview of this presentation is shown on the following pages 3 and 4.
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Superconductivity: Special physical phenomenon of some materials which appears below a material-specific low temperature $T_c$

- The superconducting state shows several special features such as
  - Electrical DC resistance disappears, i.e. lossless current transport
  - Levitation above magnets

- Very interesting for research, science and technology

- Cooling down to low temperatures is expensive $\Rightarrow T_c$ preferably as high as possible

- For decades the alloy Nb$_3$Ge was that material with the highest $T_c$, namely $-250 \, ^\circ\text{C}$, and the search for materials with higher $T_c$ was unsuccessful

Recommended reading:
- www.superconductors.org
- Book “Supraleitung: Grundlagen und Anwendungen“ by W. Buckel and R. Kleiner (in German)
Superconductivity: 1986 surprising breakthrough in Switzerland concerning higher $T_c$ and type of materials

• J. G. Bednorz and K. A. Mueller from the IBM Zurich Research Laboratory discovered in oxides \(^1\) with the chemical composition $(La,Ba)_2CuO_4$ superconductivity with $T_c = -238 °C$, i.e. $12 °C$ higher than that of $Nb_3Ge$. For their discovery they received in 1987 the Nobel Prize in physics.

\(^1\) Oxides are chemical compounds between oxygen (O) and metals

• Worldwide avalanche of research activities of unprecedented extent

⇒ Discovery of further oxides with higher $T_c$ which are likewise based on copper (Cu), e.g. $YBa_2Cu_3O_7$ with $T_c = -182 °C$ which can be cooled by liquid nitrogen ($-196 °C$) in a relatively simple and cost-effective way

⇒ March 1987 in the New York Hilton Hotel: Meeting of about 2000 physicists owing to superconductivity, known as “Woodstock in Physics“. Wave of enthusiasm due to superconductivity !

Crystal structure (crystallographic unit cell) of the high-T<sub>c</sub> superconductor YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7−y</sub>

- Layered crystal structure

- T<sub>c</sub> = −182 °C and thus its superconductivity can be maintained in a relatively simple and cost-effective way by using liquid nitrogen which has a temperature of −196 °C

- T<sub>c</sub> depends on oxygen deficiency y, highest value for y ≈ 0.07

Image: www.fom.nl/live/imgnew.db?55473

≈ 0.4 nm  1 nm = 10<sup>−6</sup> mm = 0.000001 mm
Some different manifestations of solid matter like oxides

- **Substrate**
- **Thin film**, thickness e.g. 120 nm
- **Molds** made from pressed and sintered powder
- **Crystal**
Areas of applications depend on chemical and mechanical properties of the superconducting material (raw materials, preparation, processing ...) and specific features of the superconducting state.

Examples of already realized industrial applications of so-called high-\(T_c\) superconductors which are based on copper (Cu) and oxygen (O) such as \(\text{YBa}_2\text{Cu}_3\text{O}_7\) which is cooled by liquid nitrogen:

- **Measurement and sensor technology:** Detection of very weak magnetic fields, e.g. for material testing, searching for ores, medicine
- **Communication technology:** Microwave filters
- **Electrical engineering:** Generators • Motors (e.g. for ship propulsion) • Strong electromagnets (e.g. for separation of ores) • Cables for current transport

Superconductors also have an application potential in the area of computer technology.


For further applications see page 33
Superconductivity – A quantum physical phenomenon

- Superconductivity does not only mean DC resistance $R = 0$ but comprises other phenomena, e.g. special magnetic properties like the so-called Meissner effect (see page 32), which cannot be explained solely by $R = 0$

- Peculiar quantum physical state of the so-called conduction electrons

- **Conduction electrons:** delocalized • responsible for the metallic behavior of the electrical resistivity • energetically located in close vicinity to the highest occupied states / energies, i.e. in the vicinity of the so-called Fermi energy

- Conduction electrons form pairs, so-called Cooper pairs, which consists of two electrons

- Cooper pairs form a coherent state (Bose-Einstein condensation) so that the electrons have a strong tendency to behave in the same manner or to stay in the same state

- Pair formation requires an attractive interaction between the electrons which usually repel each other because of their negative electric charge

- Attractive interaction under special conditions which are realized in some materials
  - e.g. via the so-called electron-phonon interaction, i.e. the interaction between negatively charged electrons and the oscillations of the positively charged ions of the crystal lattice
  - another possibility e.g. via so-called excitonic superconductivity, see pages 54 – 56

- For many superconductors it is not yet clarified how superconductivity comes about
Superconductivity – The presently highest \( T_c \) (established value)

Until now (July 2011) the highest established value of \( T_c \) is still \(-135 \, ^\circ C\). This is achieved by a copper (Cu)-based oxide with a layered crystal structure and complex chemical composition, namely \( \text{Hg}_{0.8}\text{Tl}_{0.2}\text{Ba}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+y} \), which was reported in 1995 by P. Dai et al. in Physica C / Superconductivity \textbf{243} (1995) 201 – 206.

Often unverified reports and rumors about materials with higher \( T_c \). For example, in the website www.superconductors.org another Cu-based oxide with higher \( T_c \) values are presented. The currently (July 2011) highest \( T_c \) claim is \(+18 \, ^\circ C\). The presented indications for superconductivity appear as relatively weak and until now they do not represent established values.

The currently highest \( T_c \) for materials without Cu:

- This is \(-220 \, ^\circ C\) which is achieved by an iron (Fe)-based oxide with a layered crystal structure, namely \( \text{GdFeAsO}_{1-y} \). Its crystal structure is of the ZrCuSiAs type and consists of alternating Fe – As and Gd – O layers.

- For the special case of superconductivity with \( T_c \) of about \(-180 \, ^\circ C\) in the system Na – W – O see page 57

Note: The most common units of temperature \( T \) are \(^\circ C\) and K. They are related by the simple conversion formula \( T [K] = T [\, ^\circ C\] + 273 \, K \)
Superconductivity – A vision

Superconductivity at room temperature!
For example a material with $T_c = + 90 \degree C$

- No cooling required $\Rightarrow$ Applications possible in many areas

- **Probably** – i.e. dependent on the properties of the material and the superconducting state – **a revolution in technology**
  including the possibility of the development of fundamentally new and entirely unexpected things

$\Rightarrow$ Superconductivity in everyday life / in everyday devices !?
Own experimental research work in the field of special oxides

Motivation: Searching for (new) oxides with interesting electric, magnetic and structural properties, especially searching for new superconductors

1989 – 1992: Doctoral thesis in the department of Dr. J. Georg Bednorz at the IBM Zurich Research Laboratory / Switzerland

1997 – 2007:

- Research scientist in the department of Prof. Dr. Jochen Mannhart at the Institute of Physics of the University of Augsburg / Germany
- Setup of three laboratories and construction of a particular procedure for the preparation of special oxides, especially with respect to a precise adjustability and control of the oxygen content of so-called reduced niobates and titanates
- Preparation of about 500 different oxides – especially in crystalline form via the melt – and study of their physical and structural properties
- Many interesting scientific results
- No indications for superconductivity with high $T_c$, but … see next page …
 Own experimental research work in the field of special oxides

- Number of possible chemical compositions is practically infinite and only a few of them have the potential to create superconductivity (at room temperature)

- Still many ideas about interesting and unexplored chemical compositions and crystal structure types in connection with the search for room temperature superconductors

- Potential for room temperature superconductivity in a special group of oxides:
  - electronically and structurally low-dimensional oxides which are not based on copper (Cu) but on titanium (Ti), niobium (Nb) or tungsten (W)
  - so-called excitonic superconductivity
  - more about that on pages 54 – 56 and in chapter 5.4 of the following cited article

- Comprehensive scientific article about the own research work in the field of special oxides: Progress in Solid State Chemistry 36 (2008) 253 – 387:

Since January 2011:

- Research scientist in the group of Prof. Dr. Nicola Spaldin at the Department of Materials of the ETH Zurich / Switzerland
A new issue on the search for room temperature superconductors

Extension of the previous approach and considerations by insights from Global Scaling – a new knowledge and holistic approach in science:

- 2005: Course in Global Scaling lectured by Dr. H. Mueller

- Intuitively gained hypothesis in 2005 / 2006:
  
  Creation of room temperature superconductivity by a resonance-like interaction between an everywhere present background field – see e.g. Global Scaling – and a special material with an appropriate crystal structure and chemical composition

- 2006 / 2007:

  Finding an useful appearing approach how to use Global Scaling to isolate such chemical compositions and crystal structure types which favor the potential for room temperature superconductivity

  ⟷ Guideline for further research is given by Global Scaling plus that which is presented on pages 13, 14 and 37 – 63 and in a comprehensive scientific article published in Progress in Solid State Chemistry 36 (2008) 253 – 387
Global Scaling – A new knowledge and holistic approach in science

The following statements and information about Global Scaling are based on

- the website of the Global Scaling Research Institute: www.global-scaling-institute.de

- an introduction into Global Scaling – the so-called Global Scaling Theory Compendium – which can be downloaded from www.global-scaling-institute.de

- the author’s
  - participation in an overall 13-day course in Global Scaling in 2005 lectured by Dr. H. Mueller at the Global Scaling Research Institute / Germany
  - attendance of several presentations at the open-door week at the Global Scaling Research Institute in Munich / Germany from 26 April – 2 May 2010. For the event program of this open-door week see www.novam-research.com/resources/Global-Scaling_Open-door-week_2010.pdf
Some essential statements of Global Scaling:

- In the universe / nature / vacuum there is an everywhere present background field in form of (eigen) oscillations (standing waves) which have a significant influence on the constitution of all processes, structures and systems in the universe, nature and (workable) technology.

- On the logarithmic axis of every physical scale – such as length \([\text{m}]\), mass \([\text{kg}]\), time \([\text{s}]\), frequency \([\text{Hz}]\), temperature \([\degree \text{C}]\) and amperage \([\text{A}]\) – there is an universal distribution of certain positions and zones, the so-called Fundamental Fractal (see pages 20 – 22 and 66), which have a special meaning and a potential effect, e.g. a high or low resonance or oscillation capability. If, which and how many of these positions and zones actually unfold their corresponding effects depends on the details of the specific system or process and on external conditions.

- Particles such as protons and electrons are considered as vacuum resonances, i.e. they are an oscillation state of the physical vacuum.

- In the universe there is a synchronicity in which all particles and matter are intimately involved. This is revealed, for example, by noise spectra of electronic components which show at different locations simultaneously the same fine structure.

- Every part of the universe, e.g. an atom, comprises the entire information of the universe.
Global Scaling – A new knowledge and holistic approach in science

- Some important key words of Global Scaling:
  - scale invariance
  - logarithm
  - fractal
  - fractal structures
  - Fundamental Fractal
  - continued fractions
  - (eigen) oscillations
  - nodes
  - gaps
  - resonance
  - proton resonance
  - vacuum resonance
  - synchronicity
  - frequency distributions
  - probability
  - compression
  - decompression
  - non-linear and fractal course of time

- Global Scaling rests, among others, upon the results of very comprehensive studies – e.g. by Prof. Simon E. Shnoll et al – of frequency distributions of many different physical, chemical and biological processes and phenomena such as radioactive decay and body masses of biological species. These studies revealed the existence of formerly unexplored physical laws and effects.

- Global Scaling was developed by Dr. Hartmut Mueller

- If you read or hear about Global Scaling for the first time, then it may take somewhat time to grasp its (unaccustomed) way of thinking, approach, concepts and insights.
Global Scaling – A new knowledge and holistic approach in science

• Global Scaling phenomena are a feature of complex and open systems or processes and are less or not at all apparent in “simple and isolated“ systems or processes

• Global Scaling allows access to complex tasks / problems / systems and is applicable in many areas such as engineering, physics, biology, (holistic) medicine, architecture, economy, optimization, prognosis, psychology …

• A Global Scaling analysis of an existing system or process may lead to a deepened understanding of its specific parameters, features and behavior

• Sketch of the approach when Global Scaling is applied with respect to the modification of an existing system or the creation of a new system:

  Question at the beginning: Is Global Scaling relevant for the corresponding task / problem / system ? • Assuming yes, then consider the positions of its associated physical quantities relative to the positions and zones which are given by the Fundamental Fractal (see page 20 – 22 and 66) • Identify the adjustable and non-adjustable quantities or parameters of the corresponding task / problem / system

  • To obtain a certain desirable result it is necessary to get an idea, hypothesis or intuition at which positions in the Fundamental Fractal the adjustable quantities or parameters have to be placed.
Global Scaling – A sketch of the Fundamental Fractal on the level $n_0$ and $n_1$

Fundamental Fractal: Universal distribution or pattern of certain positions and zones which have – on every physical scale – a special meaning and a potential effect

Consider logarithmic axis: $z = \ln \frac{x}{y}$

$x =$ physical quantity or number (ratio or set) under consideration
$y =$ calibration unit of the considered physical scale such as length [m] or mass [kg]

The positions of so-called nodes and sub-nodes – one of their potential effects is a high resonance or oscillation capability – are generated by a special continued fraction:

$$z = \ln \frac{x}{y} = \frac{3n_0}{2} + \frac{2}{n_1 + \frac{2}{n_2 + \ldots}}$$

$n_0 = \pm k \quad n_1 = \pm 3j \quad k, j = 0, 1, 2, 3 \ldots$

range of nodes and sub-nodes: $n_0 \pm 1, n_1 \pm 1$

Spectrum of discrete values on logarithmic $z$ and linear $x$ axis

nodes $z(n_0)$

$|\Delta z| = \frac{3}{2}$

sub-nodes $z(n_1)$ of $n_1 = 9, 6, 3, -3, -6, -9$
Global Scaling – A section of the Fundamental Time Fractal on the level $n_0$

$$z = \ln \frac{x}{y} = \frac{3n_0}{2} \quad n_0 = 0, \pm 1, \pm 2, \pm 3 \ldots$$

$x =$ time, e.g. elapsed time after the creation of an object or birth of a human being

$y =$ calibration unit $= 1 / f_p = \lambda_p / c = 7.01515 \times 10^{-25} \text{ s}$

$f_p =$ proton frequency, $\lambda_p = h / (2\pi c m_p)$ = reduced Compton wave length of the proton

Node positions $z(n_0)$ or $x(n_0)$ in the time fractal mark with high probability important points of change in the course of a process, independent of its nature

nodes $z(n_0)$:

- 69
- 70.5
- 72
- 73.5
- 75
- 76.5

nodes $x(n_0)$:

- 7.5 days
- 34 days
- 5 months
- 1.9 years
- 8.3 years
- 37 years

Examples of their relevance:

- At the age of 7 days a fertilized egg nests itself in the uterus
- Statistical maxima of product failure
- Based on statistical results life insurances distinguish between people below and above 37 years

Highest age of Stone Age men
Global Scaling – A section of the Fundamental Temperature Fractal on level \( n_0 \)

A possible view of (the distribution of) the \( T_c \)‘s of superconductors

\[
z = \ln \frac{x}{y} = \frac{3n_0}{2} \quad n_0 = 0, \pm 1, \pm 2, \pm 3 \ldots \quad x = \text{transition temperature } T_c \ [K]
\]

\[
y = \text{calibration unit} = m_p c^2/k = 1.08882 \times 10^{13} \text{ K}
\]

Node positions \( z(n_0) \) or \( x(n_0) \): high probability of tendency change, event attractor

Borders \( z(n_0 \pm 1) \) or \( x(n_0 \pm 1) \) of nodes: development limit

Nodes \( z(n_0) \):

-28.5 \hspace{1cm} -27 \hspace{1cm} -25.5 \hspace{1cm} -24 \hspace{1cm} -22.5

Borders / ranges of nodes \( x(n_0 \pm 1) \)

\[\begin{align*}
A & : \quad 4.6 \text{ K} \quad 20.5 \text{ K} \quad 92 \text{ K} \quad 411 \text{ K} \quad 1842 \text{ K} \\
B & : \quad 249 \text{ K} \\
C & : \quad \text{Typical } T_c \text{‘s about 400 K?}
\end{align*}\]

A: classical superconductors such as Nb\(_3\)Ge, typical \( T_c \)‘s about 20 K

B: high-\( T_c \) superconductors based on Cu and O such as \( \text{YBa}_2\text{Cu}_3\text{O}_7 \), typical \( T_c \)‘s about 100 K, often reports of indications for \( T_c \approx 240 \text{ K} \) but unverified because difficult to reproduce \( \rightarrow \) upper \( T_c \) limit of Cu-O-based superconductors?

C: \( T_c \)‘s of next generation superconductors? Typical \( T_c \)‘s about 400 K?
Global Scaling – Applications

- Large potential to create novel and advantageous technologies such as
  - Novel or more effective ways of power generation
  - Transmission of energy and data without electromagnetic pollution
  - Transmission of data and communication with an unique level of data security
  - Contactless detection of raw materials down to 10 km below the earth's surface

- Examples of already existing and running demonstration models which are ready for prototype development or production:
  - Data transmission system with an unique level of data security
  - Satellite-independent positioning system which also works in closed rooms and below the surface of the earth
  - Water splitting system which generates hydrogen and oxygen with significant less power than conventional electrolyzers

- An already commercially available Global Scaling product is “ProtoLight“ – a special light source for medical applications such as accelerated wound healing

- Further information see www.global-scaling-institute.de
Global Scaling – Information and education

• Website of the Global Scaling Research Institute: www.global-scaling-institute.de

• An introduction into Global Scaling – the so-called Global Scaling Theory Compendium – can be downloaded from www.global-scaling-institute.de


• Information about the German-language book “Global Scaling – Basis eines neuen wissenschaftlichen Weltbildes“ (in German): www.novam-research.com/resources/Global_Scaling_Buch_Info.pdf

• New, comprehensive and advanced form of education: see www.global-scaling-institute.de for further details

• Website of C. Buerger's engineering office: www.ibgs.info
Global Scaling and the search for room temperature superconductors

• Intuitively gained hypothesis:
  Creation of room temperature superconductivity by a resonance-like interaction between an everywhere present background field and a special material with an appropriate crystal structure and chemical composition

• Brief outline of an useful appearing approach how to use Global Scaling to isolate such chemical compositions and crystal structure types which favor the potential for room temperature superconductivity:
  Preparation of such materials whose readily accessible material parameters are located at special positions in the Fundamental Fractal (see pages 20 – 22 and 66). For example, this could mean that some material parameters are placed at positions with a potentially high resonance or oscillation capability, whereas others are placed at positions with a potentially low resonance or oscillation capability. Examples of readily accessible material parameters are the number and mass of atoms in the crystallographic unit cell, the lattice parameters and the chemical composition. This approach leads to a significant reduction of the number of useful appearing chemical compositions. Nevertheless, there are still many possibilities because there are various conceivable configurations of material parameters in the Fundamental Fractals which could favor the creation of room temperature superconductivity.
Global Scaling and the search for room temperature superconductors

Notes:

- For any task or question in which Global Scaling is applied, “conventional“ knowledge, experiences, results and ideas play an equal role. Therefore that which is presented on the pages 13, 14 and 37 – 63 about special oxides is still considered as relevant for the search for room temperature superconductors.

- Global Scaling can, if an useful appearing approach exists, also be applied to the search for room temperature superconductors among non-oxide materials such as organic conductors or metal-hydrogen compounds (see also pages 34 and 54 for these examples of non-oxide materials)
A positive evolution of mankind and earth does not come about solely by scientific and technological progress, but requires rather the development of the “qualities of the heart” such as compassion, peace, unconditional love, dignity, freedom, tolerance …
About the author

- Born 1962 in Bremen (Germany). 1983 – 1989: Study of physics at the University of Heidelberg (Germany)

- 1989 – 1992: Doctoral thesis in the department of Dr. J. Georg Bednorz at the IBM Zurich Research Laboratory (Switzerland). Doctorate / PhD at the University of Zurich in 1991. **Field of work:** Synthesis of oxides – especially in crystalline form via the melt – and study of their properties, solid state chemistry / physics.

- 1992 – 1997: Research scientist in the nickel metal hydride technology department of Dr. Uwe Koehler at the research center of the battery company VARTA (Germany). Two months stay as guest scientist in Tokyo (Japan) at the TOSHIBA Battery Company within a collaboration between VARTA und TOSHIBA. **Field of work:** Hydrogen storage alloys and nickel metal hydride batteries.

- 1997 – 2007: Research scientist in the department of Prof. Dr. Jochen Mannhart at the Institute of Physics of the University of Augsburg (Germany). **Field of work:** Setting up a new laboratory, synthesis of oxides – especially in crystalline form via the melt – and study of their properties, solid state chemistry / physics.

- 2005: Participation in an overall 13 - day course in Global Scaling lectured by Dr. Hartmut Mueller at the Global Scaling Research Institute (Germany).

- 2007 – 2010: Freelance work, autonomous occupation with subjects in the area of (an extended) physics / science, and creation and updating of several presentations and papers • Creation and updating of the website www.novam-research.com with the aim to disseminate information, presentations, papers and links about fundamentally new developments in science and technology such as entirely novel energy technologies

- **Since January 2011:** Research scientist in the group of Prof. Dr. Nicola Spaldin at the Department of Materials of the ETH Zurich (Switzerland): www.theory.mat.ethz.ch/people/senior_scientists/lfrank. **Field of work:** Setting up a new laboratory, synthesis of oxides and study of their properties, crystal growth via the melt, solid state chemistry / physics

- **Miscellaneous:** Author / Co-author of 70 scientific publications which are listed in the following link: www.novam-research.com/resources/Publications.pdf • Participation in several congresses and meetings about entirely novel energy technologies in Germany, Switzerland, Austria and Hungary

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More about superconductivity

• The verification of superconductivity: Zero resistance and Meissner effect

• Applications in the area of entirely novel energy technologies

• Do man-made room temperature superconductors already exist?

• Superconductivity and ECE Theory
The verification of superconductivity: The first of two essential features

Zero resistance

DC current $I$ through sample: Measurement of voltage drop $U$ at various temperatures

$$R = \frac{U}{I}$$

specific resistance or resistivity $\rho = R \frac{A}{L}$

current density $j = \frac{I}{A}$  \(L = \text{length} \quad A = \text{cross sectional area}\)

Notes: For $I > I_c$ or $j > j_c$ the superconductivity disappears

$I_c$ or $j_c$ is the so-called critical current or critical current density

For example, for YBa$_2$Cu$_3$O$_7$ the critical current density $j_c$
at $T = -196 \degree \text{C}$ is of the order of $10^6 \text{ A/cm}^2$
The verification of superconductivity: The second of two essential features

**Meissner effect**

Cooling down of the sample in an external static magnetic field $H$: Below $T_c$ superconducting currents emerge in a thin surface layer of the sample. These currents create a negative magnetic moment $M$, i.e. $M$ is antiparallel to $H$ which is called diamagnetic behavior. This magnetic moment $M$ generates an associated magnetic field which is exactly opposite to $H$ so that the total interior field of the sample vanishes. This so-called Meissner effect results from a peculiar quantum physical state of the conduction electrons and cannot be explained solely by a DC resistance $R = 0$.

Notes:

- The levitation of a superconductor above a magnet (see page 5), or vice versa, is due to the fact that a superconductor is a (strong) diamagnet. Levitation in static magnetic fields without supply of energy is possible by a diamagnetic body in a spatially inhomogeneous magnetic field. See, for example, the paper “Levitation in Physics“ by E. H. Brandt in Science 243 (1989) 349 – 355.

- For $H > H_c$ or $H_{c2}$ the superconductivity disappears. $H_c$ (for so-called type I superconductors) or $H_{c2}$ (for so-called type II superconductors) is the so-called critical field. For example, for $\text{YBa}_2\text{Cu}_3\text{O}_7$ the critical field $H_{c2}$ at $T = –196 \, ^\circ\text{C}$ is of the order of 10 Tesla. For comparison: The earth’s magnetic field is of the order of $5 \times 10^{-5}$ Tesla = 0.5 Gauss ($1 \, \text{Tesla} = 10^4 \, \text{Gauss}$).
Several applications of superconductors are presented on page 9.

Also in the area of entirely novel technologies, see e.g.

www.novam-research.com/resources/Call_to_fund_an_independent_research_facility.pdf, superconductors – especially room temperature superconductors – have an application potential. See, for example,

• page 2 in an abstract by H. V. Wenz / IEM Nova about the so-called Field Force Machine:

• pages 1 and 2 in a German-language abstract by H. V. Wenz / IEM Nova about the so-called Field Force Machine:

• section 5.1. / pages 69 – 73 in a paper by Prof. C. W. Turtur about the conversion of vacuum energy into mechanical energy:
  www.wbabin.net/physics/turtur1e.pdf
Do man-made room temperature superconductors already exist?

So-called Ultraconductors reported by Chava Energy LLC:

- See [www.chavaenergy.com/how/ultraconductors](http://www.chavaenergy.com/how/ultraconductors)
- Organic polymer materials with measured zero resistance, i.e. resistivity \( \rho < 10^{-11} \, \Omega \, \text{cm} \)
- Several anomalous electric properties such as absence of heat generation under high current
- Chava Energy continues the development of these patented materials with respect to applications and commercialization

Special metal – hydrogen materials reported by two German patent applications:

- Materials are described in the context of cold fusion and show measured zero resistance
- Further information about these materials only for licensees

In both cases: So far no public reports or statements of the presence of the Meissner effect (see page 32). Therefore it appears presently not clear if these interesting materials are really superconductors.
Superconductivity and ECE Theory

The intuitively gained hypothesis how superconductivity at room temperature may come about (see pages 15 and 25), namely

by a resonance-like interaction between an everywhere present background field – see e.g. Global Scaling – and a special material with an appropriate crystal structure and chemical composition

seems to be supported by a statement from the so-called ECE Theory which is possibly related to the hypothesis above:

“… One of the important practical consequences is that a material can become a superconductor by absorption of the inhomogeneous and homogeneous currents of ECE space-time …“

What is the ECE Theory?

• ECE stands for Einstein, Cartan and Evans and represents an unified field theory which allows a common description of the electromagnetic, gravitational, weak and strong nuclear forces

• Developed by Prof. Myron W. Evans by starting from Albert Einstein’s Theory of General Relativity and the mathematic research work of the mathematician Elie Cartan

• Some important statements:
  • Gravitation is related to curvature of space-time
  • Electromagnetism is related to torsion of space-time
  • Coupling between electromagnetism and gravitation
  • Extended electrodynamics with resonance phenomena via so-called spin connection ⇒ Possibility of extracting usable energy from space-time

• Comprehensive information about ECE Theory in the website www.aias.us

• For an introduction into ECE Theory see the article by H. Eckardt and L. G. Felker: www.aias.us/documents/eceArticle/ECE-Article_EN.pdf
On the following pages 38 – 63:

More about the own research work in the field of special oxides

• Sample preparation and oxides of the type $A_n B_n O_{3n+2}$ – also about their potential to create high-$T_c$ or room temperature superconductors

• Title, abstract and table of contents of a comprehensive scientific article on special oxides
Sample preparation of oxides

Starting materials: Commercially available oxides (e.g. Titanium oxide TiO$_2$), carbonates (e.g. Calcium carbonate CaCO$_3$) and, if necessary, metals (e.g. Niobium Nb) in form of powders.

- Powder
- Analytical balance
- Agate mortar
- Crucible and boats made from high-temperature ceramics
- Laboratory furnaces
  - typical temperatures
  - 900 – 1400 °C

Mixing of the starting materials → Heating-up of the powder mixture → Chemical solid state reaction → Formation of new oxides
Sample preparation of oxides $A_yBO_x$ with $B = \text{Ti}$, $\text{Nb}$ or $\text{Ru}$

General process for reduced, mixed-valent, conducting titanates or niobates, i.e.

$$\text{Ti}^{(4-w)^+}, \, 3d^w \quad \text{or} \quad \text{Nb}^{(5-w)^+}, \, 4d^w \quad \text{with} \quad w > 0:$$

1. Example of fully oxidized starting materials: $\text{SrCO}_3$, $\text{La}_2\text{O}_3$ and $\text{TiO}_2$ or $\text{Nb}_2\text{O}_5$

2. Pre-reaction / calcination of finely ground powder mixture at 1200 – 1300 °C in Air

   Addition of a reduced component like $\text{TiO}$ or $\text{Nb}$

3. Pressing finely ground powder mixture into two rods

   Sintering rods at 1300 – 1400 °C in Argon

Determination of oxygen content $x$ by thermogravimetry

3. Floating zone melting in Argon

   Structural analysis by powder x-ray diffraction

Fully oxidized, insulating titanates ($\text{Ti}^{4+}, \, 3d^0$) or niobates ($\text{Nb}^{5+}, \, 4d^0$) and conducting $\text{Sr}_2\text{RuO}_4$ ($\text{Ru}^{4+}, \, 4d^4$)

Lichtenberg et al:  
Sample preparation of oxides in crystalline form by floating zone melting

**Good and relatively large crystals** arise usually only if the solidification is (nearly) congruent, i.e. if the melt and the solidified material have (nearly) the same chemical composition. If this is true depends on the chemical composition and is often not known or predictable, especially for unexplored chemical compositions.
Samples / Crystals grown by floating zone melting

Example: Blue-black electrical conducting oxide $\text{Ca}_4\text{EuNb}_5\text{O}_{17}$ ($n = 5$ of $A_nB_nO_{3n+2}$)

Sketch of the perovskite-related structure of

\[ A_nB_nO_{3n+2} = ABO_x \]

\( B = \text{Ti, Nb, Ta} \)

- \( n = \text{layer thickness} \)
- \( = \text{number of BO}_6 \) octahedra along \( c \)-axis per layer

Existence of non-integral series members such as \( n = 4.5 \): Ordered intergrowth of layers with different thickness

compositional examples:

- \( n = 4 \)
  - \( ABO_{3.50} \)
  - \( \text{SrNbO}_{3.50} \)
- \( n = 4.5 \)
  - \( ABO_{3.44} \)
  - \( \text{SrNbO}_{3.44} \)
- \( n = 5 \)
  - \( ABO_{3.40} \)
  - \( \text{SrNbO}_{3.40} \)
- \( n = \infty \)
  - \( ABO_3 \) perovskite
  - \( \text{SrNbO}_3 \)

\( \Box = \text{BO}_6 \) octahedra (\( \bigcirc \) located at corners, \( B \) hidden in center)
Sketch of the pronounced structural anisotropy of $A_nB_nO_{3n+2} = ABO_x$ by using $n = 5$ as example

$B - O$ linkage:
- zig-zag along $b$-axis
- chains along $a$-axis
- interruptions along $c$-axis

$BO_6$ octahedra ($O$ located at corners, $B$ hidden in center) =

Distortion of $BO_6$ octahedra in percent typical values for $n = 5$

Often significant influence of distortions on physical properties

$A_5B_5O_{17} = ABO_{3.40} \ (n = 5)$
Some features of $A_nB_nO_{3n+2} = ABO_x$ insulators ($B = Ti^{4+}, Nb^{5+}, Ta^{5+}$):

- The highest-$T_c$ ferroelectrics are $n = 4$ types, e.g. $LaTiO_{3.50}$ ($T_c = 1770$ K)
  
  Nanamatsu et al, Ferroelectrics 8 (1974) 511

- Ferroelectrics: even $n = 2, 4, 6$ — Antiferroelectrics: odd $n = 5$

- Compounds with non-integral $n$ (see page 53),
  e.g. $CaNb_{0.89}Ti_{0.11}O_{3.44}$ ($n = 4.5$)
  Nanot et al, J. Solid State Chem. 28 (1979) 137

- Compounds known for $n = 2, 3, 4, 4.33, 4.5, 5, 6, 7$

- Complex structural details like incommensurate modulations,
  e.g. in $SrNbO_{3.50}$ ($n = 4$)

- Possibility of limited concentration of ions $B' = Al^{3+}, Fe^{3+}$ ... at $B$ site:
  
  $B = (Ti, Nb, Ta)_{1-y}B'_y$ with $y \leq 0.33$

$A_nB_nO_{3n+2} = ABO_x$ electronic conductors: No reports before 1991

The only exception: Structural study on conducting $CaNbO_x$ ($3.4 \leq x < 3.5$)

Physical properties not studied

Systematic study of $A_nB_nO_{3n+2}$ electronic conductors started by study of melt-grown LaTiO$_x = La_nTi_nO_{3n+2}$

Physical and / or structural properties depend sensitively on oxygen content $x$

Lichtenberg et al
Prog. Solid State Chem. 29 (2001) 1

Williams et al

Kuntscher et al

$\begin{align*}
\text{Ti}^{3+} & \quad 3d^1 \\
\text{Ti}^{4+} & \quad 3d^0 \\
\end{align*}$

Temperature (K)

0 100 200 300

3.0 3.1 3.2 3.3 3.4 3.5

$x$ in LaTiO$_x$

3D perovskite two phases quasi-2D

metallic semi-conducting semi-conducting ferroelectric insulator

weak ferromagnetic quasi-1D metal along $a$-axis

$n = \infty$ and 5 $n = 5$ $n = 4.5$ $n = 4.33$ $n = 4$
Resistivity $\rho(T)$ of some $A_nB_nO_{3n+2} = ABO_x$ niobates along $a$-, $b$- and $c$-axis

- Highly anisotropic conductors
- Quasi-1D metal along $a$-axis
- Metal-to-semiconductor transition at low $T$
Comprehensive studies on $A_nB_nO_{3n+2} = ABO_x$ niobates by angle-resolved photoemision (ARPES) and optical spectroscopy: Example $n = 5$ type SrNbO$_{3.41}$

ARPES probes occupied electronic states and their dispersion $E(k)$, $k = k(\theta)$

- Metal-to-semiconductor transition at $T < 100$ K
- High-resolution ARPES at 25 K, resistivity $\rho(T)$ & optical conductivity $\sigma(\nu)$ → Semiconducting state with extremely small energy gap $\Delta \approx 5$ meV, the smallest $\Delta$ of all known quasi-1D metals
- Experimental findings appear inconsistent with Peierls or 1D Mott-Hubbard picture

Comprehensive studies on \( A_nB_nO_{3n+2} = ABO_x \) niobates by ARPES, optical spectroscopy, resistivity measurements and electronic band structure calculations

\[
\begin{align*}
    n = 4 & \quad \text{Sr}_{0.8}\text{La}_{0.2}\text{NbO}_{3.50} & 4d^{0.20} & \rightarrow \text{weak quasi-1D metal} \\
    n = 4.5 & \quad \text{SrNbO}_{3.45} & 4d^{0.10} & \rightarrow \text{quasi-1D metals} \\
    n = 5 & \quad \text{SrNbO}_{3.41} & 4d^{0.18} & \rightarrow \text{small energy gap at low } T \text{ along } a\text{-axis} \\
    n = 5 & \quad \text{Sr}_{0.9}\text{La}_{0.1}\text{NbO}_{3.41} & 4d^{0.28} & \rightarrow \text{no energy gap at low } T \text{ along } a\text{-axis}
\end{align*}
\]

Special role of layers which are 5 NbO\(_6\) octahedra thick:

Electrons from the Nb ions located in the central, almost undistorted octahedra contribute most to the metallic character


LDA calculations of the electronic band structure of the $n = 5$ quasi-1D metal SrNbO$_{3.41}$

Good agreement with results from angle-resolved photoelectron spectroscopy (ARPES) with respect to lowest band

$\text{NbO}_6$ octahedron distortion =

$$\frac{(\text{largest Nb – O distance}) - (\text{smallest Nb – O distance})}{\text{average Nb – O distance}}$$

Nb atoms of least distorted octahedra contribute most to the electronic density of states (DOS) at the Fermi energy $E_F$

Quasi-1D features along $a$-axis related to octahedra distortions

LDA predicts further bands around $E_F$ which disperse along $a$- and $b$-axis, but they are not observed by ARPES: Subtle structural details? Electronic correlations? ARPES resolution?

Kuntscher et al
Phys. Rev. B
61 (2000) 1876

Winter et al
J. Phys. Cond. Matter
12 (2000) 1735

Abrahams et al
Acta Cryst. B
54 (1998) 399

Lichtenberg et al
Prog. Solid State Chem.
29 (2001) 1
Structural, compositional and electronical proximity to (anti)ferroelectric insulators!

This distinguishes them from all other known quasi-1D metals such as $\text{K}_{0.3}\text{MoO}_3$, $\text{Li}_{0.9}\text{Mo}_6\text{O}_{17}$, $\text{NbSe}_3$, $(\text{SN})_y$ and organic conductors like TTF-TCNQ.

**Examples:**

$n = 4$: ferroelectric $\text{SrNbO}_{3.5} (4d^0) \rightarrow$ weak quasi-1D metal $\text{Sr}_{0.8}\text{La}_{0.2}\text{NbO}_{3.5} (4d^{0.2})$

$n = 5$: antiferroelectric $\text{SrNb}_{0.8}\text{Ti}_{0.2}\text{O}_{3.4} (4d^0) \rightarrow$ quasi-1D metal $\text{SrNbO}_{3.4} (4d^{0.2})$

Intrinsic coexistence of metallic conductivity and large dielectric polarizability feasible in $A_nB_nO_{3n+2}$ systems!?

Usually these both features exclude each other.

Intrinsic coexistence of these both features might be useful for the creation of new high-$T_c$ superconductors.

The experimental observations presented on the following pages 51 – 53 support the presence of such an intrinsic coexistence …
Optical conductivity at $T = 300$ K along $a$- and $b$-axis of $n = 4$ ferroelectric insulator $\text{SrNbO}_{3.50}$ and $n = 4$ weak quasi-1D metal $\text{Sr}_{0.8}\text{La}_{0.2}\text{NbO}_{3.50}$.

$\uparrow$ = phonon peaks which survive in the conducting oxide

$\downarrow$ = ferroelectric soft mode (phonon peak associated with ferroelectric phase transition)

Ferroelectric soft mode peak occurs also in the weak quasi-1D metal!

Kuntscher et al
Optical conductivity at $T = 300$ K along $a$- and $b$-axis of $n = 4$ ferroelectric insulator $\text{SrNbO}_{3.50}$, $n = 4.5$ quasi-1D metal $\text{SrNbO}_{3.45}$ and $n = 5$ quasi-1D metal $\text{SrNbO}_{3.41}$

- $\downarrow$ = ferroelectric soft mode (phonon peak associated with ferroelectric phase transition)
- $\uparrow$ = phonon peaks which survive in the conducting oxides

Ferroelectric soft mode peak occurs also in the quasi-1D metals!

Kuntscher et al
Intrinsic high-frequency dielectric permittivity of the $n = 5$ quasi-1D metal SrNbO$_{3.41}$ along $c$-axis

Large permittivity: $\varepsilon_c \approx 100$

$T > 70$ K: measurement prevented by too high conductivity


$T \approx 70$ K: Metallic along $a$-axis according to ARPES and resistivity $\rho(T)$

Lichtenberg et al., Prog. Solid State Chem. 29 (2001) 1

Coexistence of large intrinsic high-frequency dielectric permittivity $\varepsilon_c \approx 100$ along $c$-axis and metallic behavior along $a$-axis!

Note: Largest possible intrinsic dielectric permittivity in non-ferroelectrics of the order of $\varepsilon_\infty \approx 100$!? Lunkenheimer et al., Phys. Rev. B 66 (2002) 052105
Potential for high-$T_c$ superconductivity in $A_n B_n O_{3n+2}$ quasi-1D conductors from the perspective of so-called excitonic superconductivity

A hypothetical possibility to realize superconductivity at room temperature is given by the so-called excitonic mechanism of superconductivity (electron-electron mediated):

- Original proposal by W. A. Little for hypothetical **quasi-1D** organic conductors$^1$:
  Conducting chains surrounded by electronically polarizable side branches
  - J. de Physique Colloque C3 Suppl. No 6 (1983) 819
  - Int. J. Quantum Chemistry (Quantum Chemistry Symposium) 15 (1981) 545
  - Scientific American 212 (1965) 21
  - Phys. Rev. 134 (1964) A1416

- Original proposal by V. L. Ginzburg for **quasi-2D** systems:
  Thin metallic sheet surrounded by two dielectric layers

---

$^1$ In connection with organic conductors we also like to refer to the essay “Approaching an Ambient Superconductor“ by Robert B. Steele from 2005: www.chemexplore.net/BookP8s.pdf
Potential for high-$T_c$ superconductivity in $A_nB_nO_{3n+2}$ quasi-1D conductors from the perspective of so-called excitonic superconductivity

Especially $n = 4.5$ and $n = 5$ interesting from W. Little's and V. Ginzburg's approach:

- quasi-2D crystal structure
- electronically quasi-1D by $B – O$ chains and delocalized electrons along $a$-axis
- electronically polarizable units by electronic band structure, fluctuating valence states of rare earth ions at $A$ site ...

Intrinsic heterostructure !? ... but electronically quasi-1D

Lichtenberg et al.
1998 – 2007: Preparation of about 400 electrically conducting oxides with different chemical composition, but no indications for high-$T_c$ superconductivity

However:

- Excitonic superconductivity only in a very small region of the compositional parameter space (W. A. Little, V. L. Ginzburg)

- “Therefore, synthesizing a room-temperature superconductor, one must pay attention to its structure: the ”distance” between failure and success can be as small as 0.01 Å in the lattice constant”.

Potential for high-\( T_c \) superconductivity in oxides with early transition metals like W, Nb or Ti

Superconducting islands with \( T_c \approx 90 \) K on the surface of Na-doped WO\(_3\)
Reich et al., J. Superconductivity 13 (2000) 855

- Strong experimental evidence for high-\( T_c \) superconductivity without Cu
- In spite of many efforts superconducting phase could not be identified
  ⇒ Research on Na – W – O was stopped

\[
\text{WO}_3 (W^{6+}, 5d^0) : \\
\text{antiferroelectric insulator with } T_c \approx 1000 \text{ K} \\
\text{distorted ReO}_3 \text{ type crystal structure – can be considered as distorted perovskite } ABO_3 \text{ with absent } A \\
\text{superconducting } Na_yWO_x (W^{(6-z)+}, 5d^z) \text{ closely related to } \text{WO}_3
\]

Speculation: Superconducting phase Na\(_y\)WO\(_x\) could be of the type \( A_nB_nO_{3n+2} \)
Many ways to modify the physical and structural properties 
by a huge number of possible chemical compositions:

- $A = \text{Na}, \text{Ca}, \text{Sr}, \text{Ba}, \text{La} \ldots$
- $B = \text{Ti}, \text{Nb}, \text{Ta} \ldots$
- Variable oxygen content $x$
- Several kinds of non-stoichiometric modifications of a certain structure type $n$ with 
  respect to its ideal composition $ABO_x$ with ideal oxygen content $x = 3 + 2/n$:
  - $A_{1-a}BO_x$  \quad $a$ = deficiency at $A$ site
  - $AB_{1-b}O_x$  \quad $b$ = deficiency at $B$ site
  - $ABO_{x-d}$  \quad $d$ = deficiency at $O$ site
  - $ABO_{x+e}$  \quad $e$ = excess at $O$ site
  - $A_{1-a}BO_{x-d}$  \quad $a$ = deficiency at $A$ site , $d$ = deficiency at $O$ site
- If there are oxygen deficiencies or at least two different ions at the $A$ (or $B$) site, 
  then they can be partially or fully ordered

Synthesis, structural, magnetic and transport properties of layered perovskite-related titanates, niobates and tantalates of the type $A_nB_nO_{3n+2}$, $A^{\prime}A_{k-1}B_kO_{3k+1}$ and $A_mB_{m-1}O_{3m}$

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Link to the submitted version (content of submitted and published version are identical): www.novam-research.com/resources/Most_recent_paper_on_special_oxides_2008.pdf
Abstract: This article represents a continuation of a paper on $A_nB_nO_{3n+2} = ABO_x$ compounds which was published in 2001. This work reports also on oxides of the type $A'A_{k1}B_kO_{3k+1}$ (Dion-Jacobson type phases) and hexagonal $A_mB_{m-1}O_{3m}$. The title materials have in common a layered perovskite-related structure whose layers are formed by corner-shared $BO_6$ octahedra. The three homologous series differ structurally in their orientation of the $BO_6$ octahedra with respect to the c-axis. This can be considered as a result from cutting the cubic perovskite $ABO_3$ structure along different directions followed by an insertion of additional oxygen, namely along the [100], [110] and [111] direction for $A'A_{k1}B_kO_{3k+1}$, $A_nB_nO_{3n+2}$ and $A_mB_{m-1}O_{3m}$, respectively. The materials, with emphasis on electrical conductors, were prepared by floating zone melting and characterized by thermogravimetric analysis, x-ray powder diffraction and magnetic measurements. On crystals of five different compounds the resistivity was measured along the distinct crystallographic directions. Concerning $A_nB_nO_{3n+2}$ this work is focussed on two topics. The first are materials with paramagnetic rare earth ions at the A site or transition metal ions such as Fe$^{3+}$ at the B site. The second are non-stoichiometric compounds. Furthermore, we discuss issues like occupational order at the B site, the proximity of some materials to the pyrochlore structure, potential magnetic ordering, and a possible coupling between magnetic and dielectric properties. The oxides $A'A_{k1}B_kO_{3k+1}$ gained attention during a study of the reduced Ba-(Ca,La)-Nb-O system which lead to conducting Dion-Jacobson type phases without alkali metals. Concerning hexagonal $A_mB_{m-1}O_{3m}$ the emphasis of this work are conducting niobates in the system Sr-Nb-O. The title materials have in common a quasi-2D (layered) structure and they are mainly known as insulators. In the case of electrical conductors, however, their transport properties cover a quasi-1D, quasi-2D and anisotropic 3D metallic behavior. Also temperature-driven metal-to-semiconductor transitions occur. A special feature of the quasi-1D metals of the type $A_nB_nO_{3n+2}$ is their compositional, structural and electronic proximity to non-conducting (anti)ferroelectrics. We speculate that these quasi-1D metals may have the potential to create new (high-$T_c$) superconductors, especially when they are viewed from the perspective of the excitonic type of superconductivity. Referring to literature and results from this work, a comprehensive overview on the title oxides and their properties is presented.
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- The periodic table of the chemical elements

- Global Scaling: A representation of the so-called Fundamental Fractal
# The periodic table of the chemical elements

**WebElements**: the periodic table on the world-wide web

[www.webelements.com](http://www.webelements.com)

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*lanthanoids*  
| lanthanum | 57  | 138.91 | La |  
| cerium   | 58  | 140.12 | Ce |  
| praseodymium | 59 | 140.90 | Pr |  
| neodymium | 60  | 144.24 | Nd |  
| promethium | 61 | 145.02 | Pm |  
| samarium | 62  | 151.96 | Sm |  
| europium | 63  | 157.25 | Eu |  
| gadolinium | 64 | 158.92 | Gd |  
| terbium | 65  | 168.93 | Tb |  
| dysprosium | 66 | 168.93 | Dy |  
| holmium | 67  | 172.97 | Ho |  
| erbium | 68  | 173.04 | Er |  
| thulium | 69  | 180.94 | Tm |  
| ytterbium | 70 | 183.84 | Yb |  

**actinoids**  
| actinium | 89  | 227.03 | Ac |  
| thorium | 90  | 232.04 | Th |  
| protactinium | 91 | 231.04 | Pa |  
| uranium | 92  | 238.03 | U  |  
| neptunium | 93 | 237.03 | Np |  
| plutonium | 94 | 244.06 | Pu |  
| americium | 95 | 243.05 | Am |  
| curium | 96  | 247.07 | Cm |  
| berkelium | 97 | 247.07 | Bk |  
| californium | 98 | 251.06 | Cf |  
| einsteinium | 99 | 252.05 | Es |  
| fermium | 100 | 257.04 | Fm |  
| mendelevium | 101 | 257.03 | Md |  
| nobelium | 102 | 259.04 | No |  

Symbols and names: the symbol and names of the elements, and their spellings are those recommended by the International Union of Pure and Applied Chemistry (IUPAC - http://www.iupac.org). Names have yet to be proposed for the most recently discovered elements (beyond 112) and so those used here are IUPAC's temporary systematic names. In the USA and some other countries, the spellings aluminium and vernonium are common while in the UK, and elsewhere the common spelling is aluminium.

Group labels: the periodic system (1–18) used here is the current IUPAC convention.

Atomic weights (mean relative masses): Apart from the heaviest elements, these are the IUPAC 2007 values and given to 5 significant figures. Elements for which the atomic weight is given within square brackets have no stable isotopes and are represented by the element's longest lived isotope reported at the time of writing.

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Image as well as more detailed information:  
[www.webelements.com](http://www.webelements.com)
Global Scaling: A representation of the so-called Fundamental Fractal on the level \( n_0 \) and \( n_1 \)

\[
z = \ln \frac{x}{y} = \frac{3}{2} n_0 + \frac{2}{n_1 + \frac{2}{n_2 + \ldots}}
\]

\( n_0 = \pm k \quad n_1 = \pm 3 j \quad k, j = 0, 1, 2, 3 \ldots \)

so-called nodes: \( n_0, z(n_0), x(n_0) \)

so-called sub-nodes: \( n_1, z(n_1), x(n_1) \)

\( x \) = physical quantity or number (ratio or set) under consideration \quad \( y \) = calibration unit of the considered physical scale such as length [m]

For further information see pages 17 – 26 and an introduction into Global Scaling, the so-called Global Scaling Theory Compendium, which can be downloaded from [www.global-scaling-institute.de](http://www.global-scaling-institute.de)