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New Physical Quantity and Unit of Type of Substance

Milan Perkovac*

MSc, Retired Professor, University of Zagreb, Croatia

***Corresponding author:** Milan Perkovac, MSc, Retired Professor, University of Zagreb, Croatia

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ABSTRACT

More than two and a half centuries ago Mr. Roger Joseph Boscovich proposed a type of substance as a physical quantity. But this could not be accepted, because there was no unit of measurement for the type of substance. Now, using the structure constant of all atoms, s_0 = 8.278691910, i.e. the fine structure constant $\alpha = 1/(2s_0^2)$, I proposed in his honor the unit "boscovich", B = α = 1/137.0734794814 = 0.0072953572, for the physical quantity the type of substance. The Mendeleev's table can be used to measure the value of that physical quantity. Because of a distinguishing number Δ in the formula of that value, its unique international tracking is necessary, for example in Sèvres near Paris. A type of substance could be called a new physical quantity, like all the other 7 basic physical quantities; m, kg, s, A, K, cd and mol, so SI (International System of Measurement Units) would thus become a system of 8 basic measurement units; m, kg, s, A, K, cd, mol, B. The new physical quantity the type of substance and its measurement unit boscovich could have a very wide application in science and in many other areas of human activity.

Keywords: Physical Quantity; Amount of Substance; Measuring Unit boscovich B; Structural Constant; Fine Structure Constant; Type of Substance

Introduction

How many physical quantities exist so far? Until now, there are several dozens of basic and derived physical quantities. Of those several dozen physical quantities, according to the international SI system, only seven (7) are basic physical quantities: https://www.nist.gov/pml/owm/metric-si/si-units. All other physical quantities are derived from the aforementioned seven basic physical quantities. Every physical quantity must have its measuring unit! Without a named measurement unit, there is no physical quantity!

Examples for SI Base Units

The following table shows examples of 7 basic SI physical quantities and their measurement units and symbol: (Table 1).

Table 1: SI Base Units.

Physical Quantity	Measuring Unit	Symbol (Unit Sign)
1. length (*l*)	meter	m
2. mass (*m*)	kilogram	kg
3. time (*t*)	second	s
4. electric current (*i*)	ampere	A
5. thermodynamic temperature (*T*)	kelvin	K
6. light intensity (*I*)	candela	cd
7. amount of substance (*n*)	mole	mol

Examples for derived physical quantities

Here are some examples for other (derived) physical quantities, which do not belong to the basic physical quantities: (Table 2)

Table 2: Examples for derived physical quantities.

Physical Quantity	Measuring Unit	Symbol (Unit Sign)
area	square meter	m^2
volume	cubic meter	m^3
speed	meter per second	$m \cdot s^{-1}$
acceleration	meter per second squared	$m \cdot s^{-2}$
volume flow	cubic meter per second	$m^3 \cdot s^{-1}$
density	kilogram per cubic meter	$kg \cdot m^{-3}$
force	newton (N)	$kg \cdot m \cdot s^{-2}$
energy, work, heat	joule (J)	$kg \cdot m^2 \cdot s^{-2}$
power	watt (W = J/s)	$kg \cdot m^2 \cdot s^{-3}$
pressure	pascal (N/m^2 = Pa)	$kg \cdot m^{-1} \cdot s^{-2}$
energy flow	joules per square meter (J/m^2)	$kg \cdot s^{-2}$
specific energy	joules per kilogram (J/kg)	$m^2 \cdot s^{-2}$
brightness	candela per square meter	$cd \cdot m^{-2}$
amount of substance concentration	mole per cubic meter	$mol \cdot m^{-3}$
... and so on for dozens of other physical quantities composed of only the 7 mentioned basic units.		

Review of the Current State of Measurement Units

Since it is in the 7 aforementioned basic physical quantities, the amount of substance as a physical quantity, which gives the answer to the question of what amount of matter (substance) we are talking about, therefore, matter undoubtedly physically exists. Since matter undoubtedly exists, then it is always a question of some kind of substance, which means that for some substance there is also a physical quantity, which gives an answer to the question of what type of this undoubtedly existing substance we are talking about. Now two questions arise: how to define the value of type of substance and which measurement unit should be chosen for this physical quantity? This article deals with the answers to these two questions, i.e. how to define the value *S* of physical quantity type of substance and what is the unit of measurement B for that type of substance?

How to Define the Value *S* of Physical Quantity Type of Substance?

Whatever substance we are talking about, that substance will consist of atoms. On the other hand, atoms are composed of a nucleus, which contains protons and neutrons, and of electrons in the outer shells of atoms. If, therefore, we decompose the type of substance into its component parts, we will have protons (p is the number of protons present), neutrons (n is the number of neutrons present) and electrons (e is the number of electrons present). If we require in advance that each type of substance be unique, i.e. that two or more substances do not coincide, then we introduce the distinguishing number Δ (Δ is an integer natural number that we artificially choose to indicate the mutual difference between substances). In this way, the value of type of substance, which we denote with *S*, according to the Frederick Soddy, who discovered isotopes of the atoms, divided by the unit of measure B, can be written like this (Figure 1), [1], Eq. (1):

$$S/B=p/10^0+n/10^4+e/10^8+\Delta/10^{12}. \quad (1)$$

The number of protons, neutrons and electrons present for each type of substance (Mendeleev's periodic table) can be determined from the interactive address http://periodictable.com/Isotopes/001.1/index.html, [2], which is shown in Figure 1.

Figure 1: The number of protons (p), neutrons (n) and electrons (e) present in the analyzed substance is determined for each type of substance. If it is determined that two or more substances have the same S/B number, then one Δ is added to each to distinguish them in accordance with Equation (1).

What is the Unit of Measurement B For the Type of Substance?

As already mentioned, each physical quantity must have its own unit of measurement. As the unit of measurement for the type of substance cannot be derived from the existing 7 base units of measurement known so far, it follows that we have to find a new unit of measurement for the physical quantity "type of substance". If an international agreement (convention) is reached, it is in principle possible to choose any size of the new measurement unit for the type of substance. My proposal, based on my earlier physical research, in which I calculated the structure constant of all atoms s_0 = 8.278691910, [2], is to name this unit boscovich, B, in honor of the man who before than two and a half centuries ago advocated the introduction of type of substance as physical quantity [3], and that the value of that unit should be equal to 1 B = α =1/(2s_0^2), that is, that it should be equal to the numerical distance between two neighboring atoms, which total number, according to the above reference (three), can be at most 2s_0^2 = 137.0734795,i.e. the numerical distance between of two adjacent atoms in Mendeleev's table is B=1/137.0734795 = 0.007295357233.

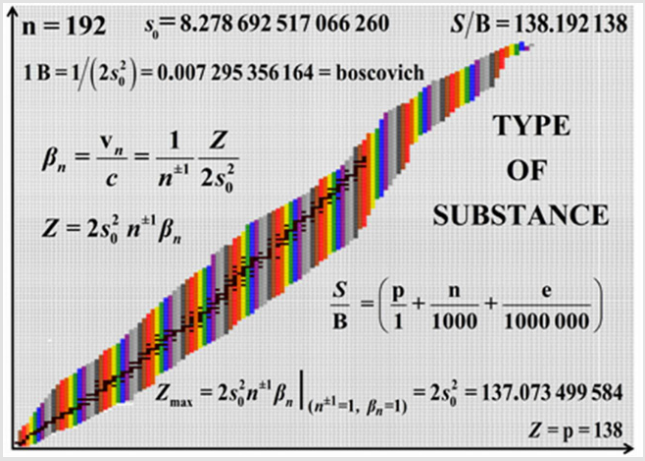

Figure 2: All elements (atoms) discovered so far are shown in color with their isotopes. Stable elements (atoms) are shown in black. Note that this figure shows the abbreviated form of S/B, and I recommend using the extended form, given by equation (1): $S/B=p/10^0+n/10^4+e/10^8+\Delta/10^{12}$. Structural constant of all atoms is s_0 = 8.278691910 and the maximum possible number of atoms is Z_{max} = 2s_0^2= 137.0734795, [3], so that the numerical distance between two adjacent atoms in Mendeleev's table which is equal as is the fine structure constant a=1/(2s_0^2)= B =1/137.0734795 = 0.0072953572.

Examples of Using the Above Results

We will now show the *S*/B results for the above Eq. (1). *S*/B ratio for vacuum, electron, neutron, proton and atoms (1 to 27), *S*/B ratio for inorganic chemistry (28 to 45) and *S*/B ratio for organic chemistry (46 to 51).

In the Table 3, Z is an ordinal number in Mendeleev's table and N is the number of atoms present.

Table 3: Examples of using formula (1).

Physical Quantity					
Type of Substance or Formula	**p**	**n**	**e**	**Δ**	***S*/B ratio, Eq. (1)**
1. Vacuum, $^{p+n=0}{}_{Z=0}\text{Vaccum}^{e=0}{}_{N=1}$	0	0	0	0	0.0000 0000 0000
2. Electron, $^{0+0=0}{}_{0}e^{0}{}_{1}$	0	0	1	0	0.0000 0001 0000
3. Neutron, $^{0+1=1}{}_{0}n^{0}{}_{1}$	0	1	0	0	0.0001 0000 0000
4. Proton, $^{1+0=1}{}_{0}p^{0}{}_{1}$	1	0	0	0	1.0000 0000 0000
5. Hydrogen, protium, $^{1+0=1}{}_{1}H^{1}{}_{1}$	1	0	1	0	1.0000 0001 0000
6. Deuterium, $^{1+1=2}{}_{1}H^{1}{}_{1}$	1	1	1	0	1.0001 0001 0000
7. Tritium, $^{1+2=3}{}_{1}H^{1}{}_{1}$	1	2	1	0	1.0002 0001 0000
8. Helium, $^{2+2=4}{}_{2}He^{2}{}_{1}$	2	2	2	0	2.0002 0002 0000
9. Carbon, $^{6+6=12}{}_{6}C^{6}{}_{1}$	6	6	6	0	6.0006 0006 0000
10. Carbon, $^{6+8=14}{}_{6}C^{6}{}_{1}$	6	8	6	0	6.0008 0006 0000
11. Nitrogen, $^{7+7=14}{}_{7}N^{7}{}_{1}$	7	7	7	0	7.0007 0007 0000
12. Oxygen, $^{8+9=17}{}_{8}O^{8}{}_{1}$	8	9	8	0	8.0009 0008 0000
13. Silicon, $^{14+14=28}{}_{14}Si^{14}{}_{1}$	14	14	14	0	14.0014 0014 0000
14. Phosphorus, $^{15+16=31}{}_{15}P^{15}{}_{1}$	15	16	15	0	15.0016 0015 0000
15. Sulfur, $^{16+16=32}{}_{16}S^{16}{}_{1}$	16	16	16	0	16.0016 0016 0000
16. Chlorine, $^{17+18=35}{}_{17}Cl^{17}{}_{1}$	17	18	17	0	17.0018 0017 0000
17. Iron, $^{26+30=56}{}_{26}Fe^{26}{}_{1}$	30	26	0	0	26.0030 0026 0000
18. Silver, $^{47+60=107}{}_{47}Ag^{47}{}_{1}$	47	60	47	0	47.0060 0047 0000
19. Thulium, $^{69+100=169}{}_{69}Tm^{69}{}_{1}$	69	100	69	0	69.0100 0069 0000
20. Iridium, $^{77+116=193}{}_{77}Ir^{77}{}_{1}$	77	116	77	0	77.0116 0077 0000
21. Platinum, $^{78+117=195}{}_{78}Pt^{78}{}_{1}$	78	117	78	0	78.0117 0078 0000
22. Gold, $^{79+118=197}{}_{79}Au^{79}{}_{1}$	79	118	79	0	79.0118 0079 0000
23. Mercury, $^{80+122=202}{}_{80}Hg^{80}{}_{1}$	80	122	80	0	80.0122 0080 0000
24. Lead, $^{82+126=208}{}_{82}Pb^{82}{}_{1}$	82	126	82	0	82.0126 0082 0000
25. Uranium, $^{92+146=238}{}_{92}U^{92}{}_{1}$	92	146	92	0	92.0146 0092 0000
26. Plutonium, $^{94+150=244}{}_{94}Pu^{94}{}_{1}$	94	150	94	0	94.0150 0094 0000
27. Oganesson, $^{118+175=293}{}_{118}Og^{118}{}_{1}$	118	175	118	0	118.0175 0118 0000
28. Water, $^{1+0=1}{}_{1}H^{1}{}_{2}\,{}^{8+8=16}{}_{8}O^{8}{}_{1}$	10	8	10	0	10.0008 0010 0000
29. Heavy water, $^{2}{}_{1}D^{1}{}_{2}\,{}^{8+8=16}{}_{8}O^{8}{}_{1}$	10	10	10	0	10.0010 0010 0000
30. Carbon dioxide, $^{12}{}_{6}C^{6}{}_{1}\,{}^{16}{}_{8}O^{8}{}_{2}$	22	22	22	0	22.0022 0022 0000
31. Carbon dioxide, $^{12}{}_{6}C^{6}{}_{1}\,{}^{16}{}_{8}O^{8}{}_{2}$	22	24	22	0	22.0024 0022 0000
32. Sulfuric acid, $^{1}{}_{1}H^{1}{}_{2}\,{}^{32}{}_{16}S^{16}{}_{1}\,{}^{16}{}_{8}O^{8}{}_{4}$	50	48	50	0	50.0048 0050 0000
33. Sulfuric acid, $^{1}{}_{1}H^{1}{}_{2}\,{}^{34}{}_{16}S^{16}{}_{1}\,{}^{17}{}_{8}O^{8}{}_{4}$	50	52	50	0	50.0052 0050 0000
34. Propane, $^{12}{}_{6}C^{6}{}_{3}\,{}^{1}{}_{1}H^{1}{}_{8}$	26	18	26	0	26.0018 0026 0000
35. Butane, $^{12}{}_{6}C^{6}{}_{4}\,{}^{1}{}_{1}H^{1}{}_{10}$	34	24	34	0	34.0024 0034 0000
36. Ethyl alcohol, $^{12}{}_{6}C^{6}{}_{2}\,{}^{1}{}_{1}H^{1}{}_{6}\,{}^{16}{}_{8}O^{8}{}_{1}$	26	20	26	0	26.0020 0026 0000
37. Glucose, $^{12}{}_{6}C^{6}{}_{6}\,{}^{1}{}_{1}H^{1}{}_{12}\,{}^{16}{}_{8}O^{8}{}_{1}$	56	44	56	0	56.0044 0056 0000

38. Sucrose, $^{12}_{6}C^{6}_{12}\,^{1}_{1}H^{1}_{22}\,^{16}_{8}O^{8}_{11}$	182	160	182	0	182.0160 0182 0000
39. Carbamic acid, $^{14}_{7}N^{7}_{1}\,^{1}_{1}H^{1}_{2}\,^{12}_{6}C^{6}_{1}\,^{16}_{8}O^{8}_{1}\,^{16}_{8}O^{8}_{1}\,^{1}_{1}H^{1}_{1}$	32	29	32	0	32.0029 0032 0000
40. Adenine, $^{12}_{6}C^{6}_{5}\,^{1}_{1}H^{1}_{5}\,^{14}_{7}N^{7}_{5}$	70	65	70	0	70.0065 0070 0000
41. Guanine, $^{12}_{6}C^{6}_{5}\,^{1}_{1}H^{1}_{5}\,^{14}_{7}N^{7}_{5}\,^{16}_{8}O^{8}_{1}$	73	78	73	0	73.0078 0073 0000
42. Glutamine, $^{12}_{6}C^{6}_{5}\,^{1}_{1}H^{1}_{10}\,^{14}_{7}N^{7}_{2}\,^{16}_{8}O^{8}$	78	68	78	0	78.0068 0078 0000
43. Chlorophyll, $^{12}_{6}C^{6}_{55}\,^{1}_{1}H^{1}_{72}\,^{16}_{8}O^{8}_{5}\,^{14}_{7}N^{7}_{4}\,^{24}_{12}Mg^{12}_{1}$	482	410	482	0	482.0410 0482 0000
44. Ascorbic acid, vitamin C, $^{12}_{6}C^{6}_{6}\,^{1}_{1}H^{1}_{8}\,^{16}_{8}O^{8}_{6}$	92	84	92	0	92.0084 0092 0000
45. Recoll dent, $[^{40}_{20}Ca^{20}_{2}\,^{31}_{15}P^{15}_{2}\,^{16}_{8}O^{8}_{7}] \times {}^{1}_{1}H^{1}_{2}\,^{16}_{8}O^{8}_{1}$	136	136	136	0	136.0136 0136 0000
in previous formula × means that the segment in the square bracket can be repeated × times.					
46. Arginine, $^{12}_{6}C^{6}_{6}\,^{1}_{1}H^{1}_{14}\,^{14}_{7}N^{7}_{4}\,^{16}_{8}O^{8}_{2}$	94	80	94	0	94.0080 0094 0000
47. Methionine, $^{12}_{6}C^{6}_{5}\,^{1}_{1}H^{1}_{11}\,^{14}_{7}N^{7}_{1}\,^{16}_{8}O^{8}_{2}\,^{34}_{16}S^{16}_{1}$	80	69	80	0	80.0069 0080 0000
48. Serine, $^{12}_{6}C^{6}_{3}\,^{1}_{1}H^{1}_{7}\,^{14}_{7}N^{7}_{1}\,^{16}_{8}O^{8}_{3}$	56	49	56	1	56.0049 0056 0001
49. Thymine, $^{12}_{6}C^{6}_{5}\,^{1}_{1}H^{1}_{6}\,^{14}_{7}N^{7}_{2}\,^{16}_{8}O^{8}_{2}$	66	60	66	0	66.0060 0066 0000
50. Cytosine, $^{12}_{6}C^{6}_{4}\,^{1}_{1}H^{1}_{5}\,^{14}_{7}N^{7}_{3}\,^{16}_{8}O^{8}_{1}$	58	53	53	0	58.0053 0058 0000
51. Uracil, $^{12}_{6}C^{6}_{4}\,^{1}_{1}H^{1}_{4}\,^{14}_{7}N^{7}_{2}\,^{16}_{8}O^{8}_{2}$	58	54	58	0	58.0054 0058 0000

Discussion

It is evident from the previous examples that each physical quantity is represented by the corresponding Soddy number *S* boscovich, B or abbreviated by the ratio *S*/B. In this way, every existing substance or substance that will be created in the future can be described in the way shown. It is assumed that the application of the new physical quantity and its measurement unit boscovich is possible in an extremely large number of cases, starting from production, storage, the pharmaceutical industry [4] , all the way to landfills and waste sorting and processing, in the everyday field of human activity. This way of measuring and processing measurement data enables the use of bar codes and QR codes that can be used in this way with all kinds of substances, and this can be one of the biggest advantages of using a new physical quantity and its measurement unit. This can also represent a step forward for new research and development in the field of natural and social sciences. Below is a historical account of the work of Rogerio Joseph Boscovich from 1763, and the basis for the proposal to name the "boscovich", B to the unit of measurement for the type of substance (Figure 3).

Figure 3: The book (in the picture above) "THEORIA PHILOSOPHIÆ NATURALS, P. ROGERIO JOSEPHO BOSCOVICH, VENETIIS,MDCCLXIII (1763.) Theory of Natural Philosophy" which was printed in Venice in 1763 in which J.R. Boscovich presents his ideas about atoms and types of substance, and (in the picture below) a banknote with the image of J.R. Boscovich printed in Croatia in 1993.

Conclusion

The article presents a ten-year research work on finding a new physical quantity, for which physical quantity the author proposes the name type of substance (unit sign *S*), and determining its unit of measurement (for which unit the author proposes the name boscovich, unit sign B), which was prompted by questions from students about how physical quantities, which indisputably exist, can be expressed from existing 7 basic measurement units of the SI system (m, kg, s, A, K, cd, mol). After it became clear that the existing SI system with its mentioned 7 basic measurement units is not able to describe, for example, smell, which is undeniably a physical quantity, it turned out that in addition to the mol, which measures the amount of substance, there is a possibility and a need to introduce a new measuring unit for type of substance. The article provides answers to two key questions, namely, how a type of substance is defined and offers a proposal for a unit of measurement for a type of substance. Measurement results for particles and atoms based on Mendeleev's table are also presented. It is shown that any substance can be expressed using the introduced Soddy number *S* and the boscovich unit of measurement B, or their ratio *S*/B. According to the obtained results, the application of the presented solutions is possible in a very wide area of human activity. Now the international system of SI units could be expanded from the existing seven to eight basic measurement units (m, kg, s, A, K, cd, mol, B). Given that measurement units are woven into every pore of human life, all of the above can be an incentive for the development of science as a whole.

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