



Prize Winner

Science Writing Year 8

Gunin Singhal

St Peter's College

Oliphant Science Awards 2019

Science Writing

From Alchemy to Chemistry: The development of the periodic table

How I (the Periodic Table) came to be

1

IA

11A

1

H

Hydrogen

1.008

2

IIA

2A

2

He

Helium

4.003

3

Li

Lithium

6.941

4

Be

Beryllium

9.012

5

B

Boron

10.811

6

C

Carbon

12.011

7

N

Nitrogen

14.007

8

O

Oxygen

15.999

9

F

Fluorine

18.998

10

Ne

Neon

20.180

11

Na

Sodium

22.990

12

Mg

Magnesium

24.305

13

Al

Aluminum

26.982

14

Si

Silicon

28.086

15

P

Phosphorus

30.974

16

S

Sulfur

32.066

17

Cl

Chlorine

35.453

18

Ar

Argon

39.948

19

K

Potassium

39.098

20

Ca

Calcium

40.078

21

Sc

Scandium

44.956

22

Ti

Titanium

47.88

23

V

Vanadium

50.942

24

Cr

Chromium

51.996

25

Mn

Manganese

54.938

26

Fe

Iron

55.933

27

Co

Cobalt

58.933

28

Ni

Nickel

58.693

29

Cu

Copper

63.546

30

Zn

Zinc

65.39

31

Ga

Gallium

69.723

32

Ge

Germanium

72.61

33

As

Arsenic

74.922

34

Se

Selenium

78.09

35

Br

Bromine

79.904

36

Kr

Krypton

84.80

37

Rb

Rubidium

84.468

38

Sr

Strontium

87.62

39

Y

Yttrium

88.906

40

Zr

Zirconium

91.224

41

Nb

Niobium

92.906

42

Mo

Molybdenum

95.94

43

Tc

Technetium

98.907

44

Ru

Ruthenium

101.07

45

Rh

Rhodium

102.906

46

Pd

Palladium

106.42

47

Ag

Silver

107.868

48

Cd

Cadmium

112.411

49

In

Indium

114.818

50

Sn

Tin

118.71

51

Sb

Antimony

121.76

52

Te

Tellurium

127.6

53

I

Iodine

126.904

54

Xe

Xenon

131.29

55

Cs

Cesium

132.905

56

Ba

Barium

137.327

57-71

Lanthanide Series

72

Hf

Hafnium

178.49

73

Ta

Tantalum

180.948

74

W

Tungsten

183.85

75

Re

Rhenium

186.207

76

Os

Osmium

190.23

77

Ir

Iridium

192.22

78

Pt

Platinum

195.08

79

Au

Gold

196.967

80

Hg

Mercury

200.59

81

Tl

Thallium

204.383

82

Pb

Lead

207.2

83

Bi

Bismuth

208.980

84

Po

Polonium

[209]

85

At

Astatine

209.987

86

Rn

Radon

222.018

87

Fr

Francium

223.020

88

Ra

Radium

226.025

89-103

Actinide Series

104

Rf

Rutherfordium

[261]

105

Db

Dubnium

[262]

106

Sg

Seaborgium

[266]

107

Bh

Bohrium

[264]

108

Hs

Hassium

[269]

109

Mt

Meitnerium

[268]

110

Ds

Darmstadtium

[269]

111

Rg

Roentgenium

[272]

112

Cn

Copernicium

[277]

113

Uut

Ununtrium

unknown

114

Fl

Flerovium

[289]

115

Uup

Ununpentium

unknown

116

Lv

Livermorium

[293]

117

Uus

Ununseptium

unknown

118

Uuo

Ununoctium

unknown

57

La

Lanthanum

138.905

58

Ce

Cerium

140.115

59

Pr

Praseodymium

140.908

60

Nd

Neodymium

144.24

61

Pm

Promethium

144.913

62

Sm

Samarium

150.36

63

Eu

Europium

151.966

64

Gd

Gadolinium

157.25

65

Tb

Terbium

158.925

66

Dy

Dysprosium

162.50

67

Ho

Holmium

164.930

68

Er

Erbium

167.26

69

Tm

Thulium

168.934

70

Yb

Ytterbium

173.04

71

Lu

Lutetium

174.967

89

Ac

Actinium

227.028

90

Th

Thorium

232.038

91

Pa

Protactinium

231.036

92

U

Uranium

238.029

93

Np

Neptunium

237.048

94

Pu

Plutonium

244.064

95

Am

Americium

243.061

96

Cm

Curium

247.070

97

Bk

Berkelium

247.070

98

Cf

Californium

251.080

99

Es

Einsteinium

[254]

100

Fm

Fermium

257.095

101

Md

Mendelevium

258.1

102

No

Nobelium

259.101

103

Lr

Lawrencium

[262]

Alkali Metal

Alkaline Earth

Transition Metal

Semimetal

Nonmetal

Basic Metal

Halogen

Noble Gas

Lanthanide

Actinide

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Cover Image: The Periodic Table

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The story of my creation is like none other. Everyday creations happen in art studios, in factories, on assembly lines, you name it. But I think that my story of creation is the best, because it took centuries to create me! A plethora of hardworking scientists failed over and over again while trying to work out relationships in between my body parts and finally created a version of me that allows me to still grow and develop! In fact, I am such a fascinating a creation that there are songs about me, as well as different gaming versions of me. I am the Periodic Table, and today, in the year of my 150th birthday, I will take you on a journey that will show you how I, the Periodic Table, came to be.

Alchemy

The seeds of my creation were sowed with the ancient practice of Alchemy which sought to change metals such as lead into gold, the most spiritually perfect substance. Alchemy practitioners believed that substances like lead and gold, two of my many parts, consisted of fire, air, water and earth. By changing the proportions of inferior substances like lead, they could be made to have perfect proportions, in other words, gold. Alchemy practitioners believed a mythical substance Philosopher's Stone existed, which not only gave immortality and the power to heal, but could change substances into gold. ^[1] Alchemy provided some insight, albeit incorrect, into composition of substances and provided key clues in centuries to come that helped create me.

Early Creations

The quest for the Philosophers stone continued into the 17th century when Newton wrote about creating philosophic mercury as a step towards creating the philosopher's stone. In 1669, a German merchant, Henning Brand, attempted to make the stone, but instead produced a glowing white substance while experimenting with distilled human urine. This substance was phosphorus, which was rediscovered by Robert Boyle in 1680. This discovery redefined what it meant for a substance to be an element. ^[2]

One of the earliest recorded attempts to bring me to life was in 1789, when Antione Lavoisier grouped my body parts (the elements) based on gases, non-metals and metals. This provided one of the major keys to arranging the elements. Even today my basic form reflects the above groups. ^[3]

In 1829, Johann Döbereiner placed my elements into groups of three that had similar chemical properties. One of these triads was lithium, sodium and potassium. He also demonstrated that the properties of the two outer elements in the set (i.e. lithium and potassium) could provide a reasonable prediction about the chemical properties of the middle element (i.e. sodium). ^[3]

It was not until 1860, that an accurate list of the atomic mass of the elements was made available. This led to major discoveries about the relationships in between different elements and then the creation of me. ^[3]

Identifying Patterns

In 1862, French scientist Alexandre Beguyer de Chancourtois created a 3D version of me called the Telluric Screw. I was a cylinder, with the elements plotted on my outer surface, based on their atomic weight. One full turn meant the atomic weight had increased by 16. It was one of the first attempts that showed that similar elements appear at periodic intervals based on weight. ^[3]

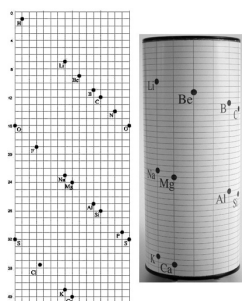


Image 1: The Telluric Screw

An English scientist, John Newlands, noted another pattern occurring with my elements; every seventh element had similar properties to each other and he called this the Law of Octaves. ^[4] However, this law didn't work for elements after calcium. ^[5] As well as this, the noble gases hadn't been discovered yet. Originally, Newlands left gaps in me for undiscovered elements, ^[6] but abolished this idea, and ordered elements strictly to atomic mass, which made him put some of my elements in groups in which they didn't belong. For example, he put Iron, a metal, into the same group as Oxygen and Sulphur, which are non-metals. ^[7] As well as this, Newlands fitted two elements into one box, which is why the Chemical Society didn't publish his version of me. ^{[3][7]} Despite this, Newlands was on the right track as a later discovery showed that similar properties in my body parts occur when a set of ns^2np^6 subshells are filled. ^[5] Discovery by discovery, the world was getting closer to bringing me into the world.

Newlands' Octaves						
H	Li	Ga	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co, Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce, La	Zr	Di, Mo	Ro, Ru
Pd	Ag	Cd	U	Sn	Sb	Te
I	Cs	Ba, V	Ta	W	Nb	Au
Pt, Ir	Tl	Pb	Th	Hg	Bi	Cs

Image 2: John Newlands' Periodic Table

Julius Lothar Meyer was the scientist who came closest to bringing me into the world. He made me initially with 28 elements, later incorporating all the discovered transition metals at the time with the final version containing 56 elements. He arranged the elements in me as per their atomic volume which is atomic mass (grams/mole) divided by density (grams/cubic centimetre)^[5]. Elements with the same valency were located in the same line.^[3] He plotted the element's atomic volume against the atomic mass. Noble gases weren't discovered at the time, which is why alkali metals appear on the peaks and then metals on the downslopes and in the valleys.^[5] The non-metals occur on the rising sections of the graph. Unfortunately, this version of me was published a year after Mendeleev's version of me was published.

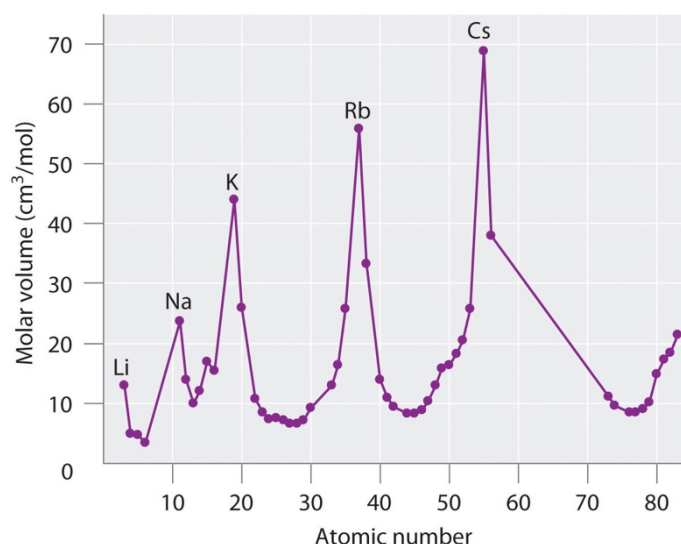


Image 3: Meyer's Graph

Dimitri Mendeleev

Mendeleev was a Russian Scientist credited with the creation of the modern-day Periodic Table (me)! He wrote down the names of my elements and their respective properties onto cards and kept on arranging them in new patterns. He finally discovered that by arranging the elements in order of increasing atomic weight, certain elements with similar properties regularly occurred. For example, he noticed that a reactive non-metal was followed by a very reactive light metal and then a less reactive light metal.^[3] He also arranged the elements according to how many oxygen or hydrogen molecules it took for the element to form compounds. For example, hydrogen, lithium, sodium, and potassium all reacted with one oxygen molecule to form compounds. These created groups, similar to the groups in my table today.^[5]

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=40	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Figure 7.1.3: Mendeleev's Periodic Table, as Published in the German Journal *Annalen der Chemie und Pharmacie* in 1872. The column headings "Reihen" and "Gruppe" are German for "row" and "group." Formulas indicate the type of compounds formed by each group, with "R" standing for "any element" and superscripts used where we now use subscripts. Atomic masses are shown after equal signs and increase across each row from left to right.

Image 4: Mendeleev's Initial Table

If Mendeleev noticed two elements with similar properties were in different columns, he swapped the elements around so that they fitted with this pattern. For example, based on atomic weight, iodine and tellurium should be the other way around, but their properties originally fell with different elements to the ones above them. Mendeleev swapped them around so my two body parts would perfectly align with the elements above them, and this is how I currently appear. ^[3]



Image 5: My Father, Dimitri Mendeleev

One of the main features of Mendeleev's version of me was leaving empty spaces for elements that were undiscovered at the time. He recognized that there were places where my body parts should have been as per his pattern and realized that these spaces actually contained undiscovered elements. He used these patterns and similarities to predict features for five undiscovered elements. Three of these elements were discovered within the next 15 years and fitted in with Mendeleev's predictions. One of these elements that Mendeleev predicted was Gallium, which he called Eka-aluminium, because it was the element underneath aluminium. The similarities in between the two elements are listed in the table below. ^[3]

Table 1: The predictions made by Mendeleev compared to the actual properties of Gallium. ^[3]

Properties	Eka-aluminium	Gallium
Atomic Weight	About 68	69.72
Density of solid	6.0g/cm ³	5.9g/cm ³
Melting point	Quite low	29.78°C
Valency	3	3
Method of discovery	Probably from it's spectrum	Spectroscopically
Oxide	Formula: Ea ₃ O ₃ Density: 5.5g/cm ³ Soluble in acids and alkalis	Formula: Ga ₂ O ₃ Density: 5.88g/cm ² Soluble in alkalis and acids

Post Mendeleev Contributions to the Periodic Table

After Mendeleev created my shape and structure, other contributions were made to my appearance. In 1894, Sir William Ramsay and Lord Rayleigh discovered a new group of elements - the noble gases (helium, neon, argon, krypton and xenon). ^[9] Argon was the first to be discovered. Ramsay followed the same logic as Mendeleev and realised there was a niche in between chlorine (a halogen) and potassium (an alkali metal) where he could fit argon. Ramsay realised this niche was there for all of the other new elements, and created Group 0 for the noble gases, and later, Ramsay's placements were validated. ^[5] This added further proof that my elementary composition was correct. ^[4]

In 1913, Henry Mosely, an English scientist worked out why elements like Iodine and Tellurium had to be swapped around. He determined the atomic number of all the discovered elements through studying the x-rays emitted by the elements. ^[5] Through this, he realised that if the elements were arranged based on atomic number instead of atomic weight, it would explain why elements such as

iodine and tellurium needed to be swapped. ^[4] Mosely also noticed three gaps in his table of x-ray frequencies, so he predicted three new elements – Technetium, Promethium and Rhenium. ^[5]

In 1945, a scientist named Glenn Seaborg created two of my appendages! He created a new group called the actinide series, which consisted of elements that were already known. Seaborg realised these elements belonged to a separate group and so accordingly published a new version of Mendeleev's table with the lanthanides and actinides under my main body.

Today

Centuries ago, anyone could propose a modification to my appearance. Since then, things have changed. Today, only the IUPAC (International Union of Pure and Applied Chemistry) can verify the addition of new elements. ^[4] Since the completion of the seventh period with the discovery of Oganesson, many new theories have been proposed as to how many other elements there could potentially be. One of the horrifying things that has come out of this research is that any extension of me would feature elements that would disrupt the perfect pattern my father found 150 years ago. If this research is to be found true, my whole appearance could be changed! ^[2] And after centuries of work that started with trying to find the philosophers stone, to some of my body parts only being discovered a few years ago, I don't want any more change. I'm scared.

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Images

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