Mendeleev's Periodic Table

CK12 Editor

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CONCEPT 1 Mendeleev's Periodic Table

Lesson Objectives

- Describe the method Mendeleev used to make his periodic table.
- List the advantages and disadvantages Mendeleev's table had over other methods of organizing the elements.
- Explain how our current periodic table differs from Mendeleev's original table.

Introduction

During the 1800s, when most of the elements were being discovered, many chemists tried to classify the elements according to their similarities. In 1829, Johann Döbereiner noted chemical similarities in several groups of three elements and placed these elements into what he called triads. His groupings included the triads of 1) chlorine, bromine, and iodine; 2) sulfur, selenium, and tellurium; 3) calcium, strontium, and barium; and 4) lithium, sodium, and potassium. In all of the triads, the atomic weight of the second element was almost exactly the average of the atomic weights of the first and third element.

In 1864, John Newlands saw a connection between the chemical properties of elements and their atomic masses. He stated that if the known elements, beginning with lithium, are arranged in order of increasing mass, the eighth element will have properties similar to the first, the ninth similar to the second, the tenth similar to the third, and so on. Newlands called his relationship the law of octaves (illustrated in Figure 1.1), comparing the elements to the notes in a musical scale. Newlands tried to force all the known elements to fit into his octaves, but many of the heavier elements discovered later did not fit into his patterns.

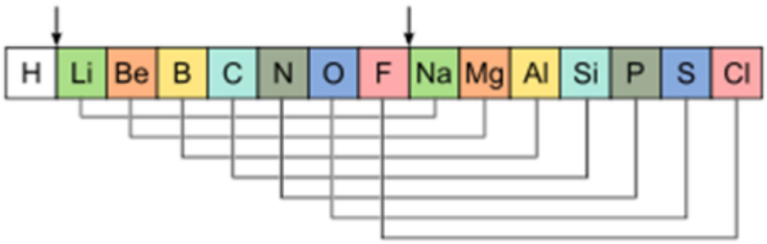
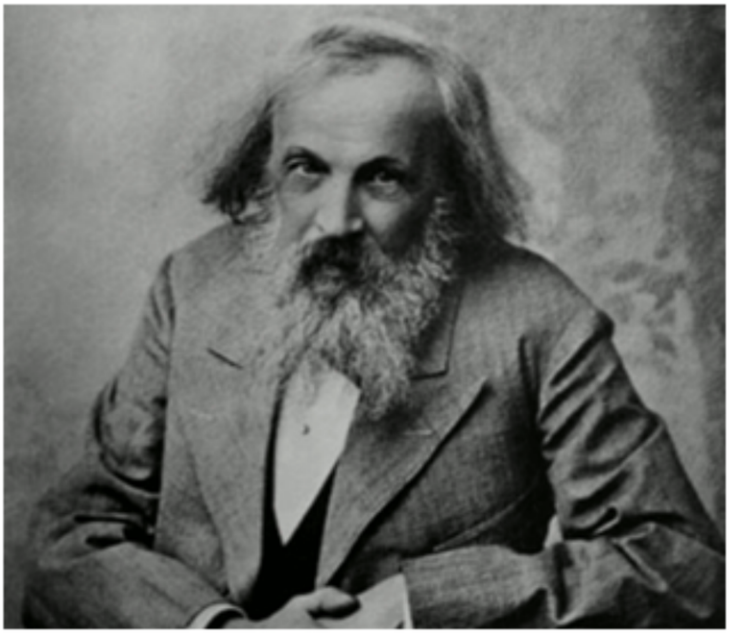


FIGURE 1.1
John Newlands's law of octaves.

Mendeleev Organized His Table According to Chemical Behavior

By 1869, a total of 63 elements had been discovered. As the number of known elements grew, scientists began to recognize patterns in the way chemicals reacted and began to devise ways to classify the elements.

Dmitri Mendeleev, a Siberian-born Russian chemist, was the first scientist to make a periodic table much like the one we use today. Mendeleev's table listed the elements in order of increasing atomic weight and placed elements with similar chemical behavior underneath each other. For example, lithium is a shiny metal, soft enough to be cut

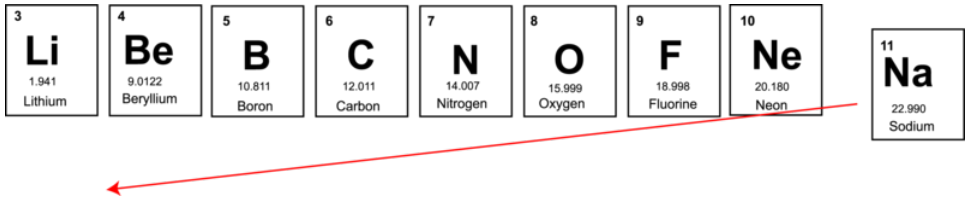


Dmitri Mendeleev

FIGURE 1.2

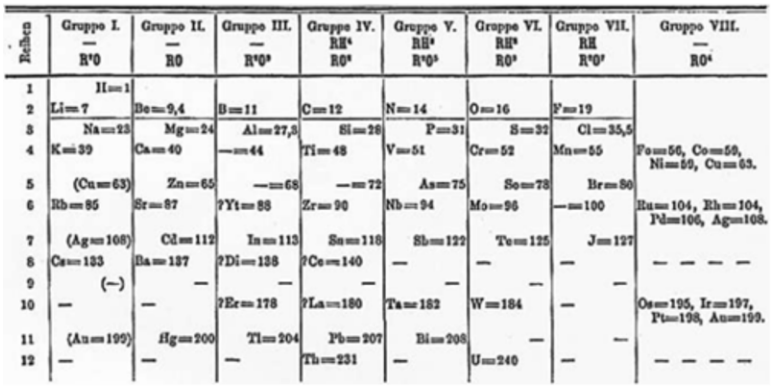
Dmitri Mendeleev created the first periodic table.

with a spoon. It reacts readily with oxygen and reacts violently with water. When it reacts with water, it produces hydrogen gas and lithium hydroxide. The next element, in terms of increasing mass, with a similar chemical behavior is sodium. Sodium is a shiny metal, soft enough to be cut with a spoon. It reacts readily with oxygen and reacts violently with water. When it reacts with water, it produces hydrogen gas and sodium hydroxide. When Mendeleev found an element whose chemistry was very similar to a previous element, he placed it below the similar element, as seen in the illustration below.



Mendeleev avoided Newlands' mistake of trying to force elements into groups where their chemistry did not match, but he still ran into a few problems as he constructed his table. In order to group elements with the same chemical behavior together, Mendeleev occasionally broke the trend of listing the elements by increasing atomic weight. For example, if you look at iodine and tellurium on the periodic table, you will see that tellurium is heavier than iodine. In Mendeleev's table (shown in Figure 1.3), he listed tellurium before iodine because iodine's properties are most similar to those of fluorine, chlorine, and bromine. Additionally, tellurium has more properties in common with the oxygen group than with the fluorine group.

Another problem Mendeleev encountered was that sometimes the next heaviest element in his list did not fit the properties of the next available place on the table. He would skip places on the table, leaving holes, in order to put the element in a group with elements with similar properties. For example, when Mendeleev was creating his table, the elements gallium and germanium had not yet been discovered. After zinc, arsenic was the next heaviest element he knew about, and the boron group was the next available place on his table. However, arsenic had properties that



Reihen	Gruppo I. — R^1O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo 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=140	—	—	—	— — — —
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 1.3

Mendeleev's 1869 periodic table

were most similar to the properties of nitrogen and phosphorus, not boron. Instead of listing arsenic right after zinc, Mendeleev left two holes in his table for what he claimed were undiscovered elements.

Mendeleev went further with his claim by predicting what properties the missing elements should have. From looking at Mendeleev's 1869 periodic table, you can see that the element below aluminum is missing. He predicted that an element he called eka-aluminum would belong there and would have some of the properties listed in Table **??**. When the element gallium was later discovered, it was found to have many of the qualities predicted by Mendeleev.

TABLE 1.1:

Property	**Eka-aluminium**	**Gallium**
atomic weight	68	69.72
density (g/cm^3)	6.0	5.904
melting point (°C)	Low	29.78
oxide's formula	Ea_2O_3 (density - 5.5 g cm^{-3}) (soluble in both alkalis and acids)	Ga_2O_3 (density - 5.88 g cm^{-3}) (soluble in both alkalis and acids)
chloride's formula	Ea_2Cl_6 (volatile)	Ga_2Cl_6 (volatile)

Mendeleev made similar predictions for an element to fit in the place next to silicon. Germanium, isolated in 1882, provided the best confirmation of the theory up to that time, due to its contrasting more clearly with its neighboring elements than the two previously confirmed predictions of Mendeleev do with theirs.

TABLE 1.2:

Property	**Eka-silicon**	**Germanium**
atomic mass	72	72.61
density (g/cm^3)	5.5	5.35
melting point (°C)	high	947
color	grey	grey
oxide type	refractory dioxide	refractory dioxide
oxide density g/cm^3	4.7	4.7
oxide activity	feebly basic	feebly basic
chloride boiling point	under 100°C	86°C ($GeCl_4$)
chloride density (g/cm^3)	1.9	1.9

How was Mendeleev able to make such accurate predictions? He understood the patterns that appeared between elements within a family, so he was able to fill in the missing pieces of the patterns. The ability to make accurate predictions about previously undiscovered elements is what set Mendeleev's table apart from other organizational systems developed at the same time. This is what eventually led scientists to accept his table.

number, and therefore organized the table by nuclear charge (or atomic number) rather than atomic weight. Thus Moseley placed argon (atomic number 18) before potassium (atomic number 19) based on their X-ray wavelengths, despite the fact that argon has a greater atomic weight (39.9) than potassium (39.1). The new order agrees with the chemical properties of these elements, since argon is a noble gas and potassium an alkali metal. Similarly, Moseley placed cobalt before nickel, and was able to explain that tellurium occurs before iodine without revising the experimental atomic weight of tellurium (127.6) as proposed by Mendeleev.

Moseley's research also showed that there were gaps in his table at atomic numbers 43 and 61 which are now known to be Technetium and Promethium, respectively, both radioactive and not naturally occurring. Following in the footsteps of Dmitri Mendeleev, Henry Moseley also predicted new elements.

You are going to see that the elements in vertical columns are related to each other by their electron configuration but remember that Mendeleev did not know anything about electron configuration. He placed the elements in their positions according to their chemical behavior. Thus, the vertical columns in Mendeleev's table were composed of elements with similar chemistry. These vertical columns are called groups or families of elements.

Lesson Summary

- Dmitri Mendeleev created the first periodic table that is very similar to the one used today.
- Mendeleev organized the elements in order of increasing atomic mass and in groups of similar chemical behavior. He also left holes for missing elements and used the patterns of his table to make predictions of properties of these undiscovered elements.
- The modern periodic table now arranges elements in order of increasing atomic number. Additionally, more groups and elements have been added as they have been discovered.

Vocabulary

Periodic table A tabular arrangement of the chemical elements according to atomic number.

Mendeleev The Russian chemist credited with organizing the periodic table in the form we use today.

Moseley The chemist credited with finding that each element has a unique atomic number.

Further Reading / Supplemental Links

- Tutorial: Vision Learning: The Periodic Table http://visionlearning.com/library/module_viewer.php?mid=52&l=&c3=
- How the Periodic Table Was Organized (YouTube): http://www.youtube.com/watch%3Fv%3DCdkpoQk2LDE
- For several videos and video clips describing the periodic table, go to http://www.uen.org/dms/. Go to the k-12 library. Search for "periodic table." (username to pioneer: pioneer; password: time)

Review Questions

1. What general organization did Mendeleev use when he constructed his table?
2. How did Mendeleev's system differ from Newlands's system?
3. What characteristics placed elements in the same group?
4. Did all elements discovered at the time of Mendeleev fit into this organization system? How would the discovery of new elements have affecting Mendeleev's arrangement of the elements? What flaws did his system have?
5. Look at Mendeleev's predictions for germanium (eka-silicon). How was Mendeleev able to make such accurate predictions?
6. What problem did Mendeleev have when arranging the elements according to his criteria? Give a specific example.
7. What advantages did Mendeleev's system have over other arrangement systems?
8. What discovery did Henry Moseley make that changed how we currently recognize the order of the elements on the periodic table?