
It's in the Cards

Discovering the Periodic Law

Introduction

Dmitri Mendeleev's discovery of the Periodic Law ranks as one of the greatest achievements in the history of science. It has survived the test of time and stands to this day as the single most important tool to understand the chemistry of the elements. As we try to understand the essence of this great discovery, it is worthwhile to go back in time and look at how it was achieved. What did Mendeleev know and when did he know it?

Concepts

- Periodic law
- Atomic Mass
- Periodic Table
- Ionization energy

Background

In the years 1868–1870, Dmitri Mendeleev, a professor of chemistry at the University of St. Petersburg in Russia, was intent on writing a new textbook of chemistry, called *Principles of Chemistry*. More than 60 individual elements were known, and a great many facts had been discovered about their properties and compounds. Mendeleev knew the atomic masses of the elements, their densities, boiling points, melting points, the formulas of their compounds with hydrogen, oxygen, and chlorine, and many other isolated facts. What was missing was a way to organize these facts, a way to understand how individual facts related to each other – in short, a way to classify the elements. The following quote is translated from Mendeleev's first published report of the periodic law:

"I wished to establish some sort of system of elements in which their distribution is not guided by chance...but by some sort of definite and exact principle."

Mendeleev decided to arrange the elements systematically according to their atomic mass. He wrote out the exact atomic masses (as they were known at the time) in the margin of a list of the elements, then wrote out separate cards for each of the elements, with their atomic mass and important chemical and physical properties. Using these cards, Mendeleev played "chemical solitaire" for several hours, finally copying to a sheet of paper the arrangement he had worked out with the cards. With slight modification, this became Mendeleev's first *Periodic Table of the Elements*.

Experiment Overview

The purpose of this activity is to re-create Mendeleev's discovery of the classification of elements and the periodic law using a special deck of element cards. The real properties of the elements, but not their names or symbols, are written on these cards. As the cards are arranged and rearranged based on logical trends in some of these properties the nature of the periodic law should reveal itself

Pre-Lab Questions

The element cards list all of the following properties for each element. Use your textbook to write a clear definition of each property. Give the typical units for each numerical property, if appropriate.

- Ionization energy
- Atomic radius
- Melting point
- Atomic mass
- Density
- Electronegativity

Materials

Special deck of 31 element cards

Procedure

1. Form a research group with two or three other students. Obtain a deck of element cards and spread the cards out on the lab table.
2. Each card list the properties of a single element (X), as shown below:

Ionization energy

Atomic radius

Atomic mass

Formula of its oxide X_bO_c

Formula of its chloride XCl_a

Melting point

Density*

Formula of its hydride XH_d

Electronegativity

*Density values are in units of g/cm^3 for solids and liquids, g/L for gasses.

3. Working in a collaborative manner, discuss the possibilities for arrangement of the element cards with all members of the group, and look for a logical arrangement of the cards. Consider the following questions:
 - What are the similarities and differences along the elements?
 - Are there any numerical or logical trends in their properties?
4. It is NOT within the rules of this game of chemical solitaire to look up information in a textbook or use a modern periodic table as a guide.

Mendeleev's greatest insight in creating the periodic table was in recognizing there were some gaps when the elements were arranged in logical order. He had the courage not only to leave blanks in his table for missing elements, but also predict their properties.

5. One of the element cards is also missing in your deck of cards, Decide where the missing element belongs in the arrangement of the elements and rearrange the cards if necessary to accommodate the missing elements.
6. On the Data Sheet, fill in the *Table of the Elements* to illustrate a logical arrangement of the element cards. To do this, write down only the *atomic mass* of each element, as shown on its card. Leave a blank space for the missing element. *Note:* the table is 8 x 8 and contains 32 more squares than are needed—plenty of room to arrange the elements in many different ways.
7. Predict the properties of the missing element by averaging the properties of its nearest neighbors (in any direction). On the Data Sheet, complete the card for the missing element by entering its predicted properties alongside the name of each property.