Valence and the Periodic Table

Skills to Develop

- Understand and describe how the periodic table was first organized

Many chemists were interested in knowing the "chemical equivalents" of different substances. For instance, what mass of acid A neutralizes base B? These numbers were easy to measure and practically useful. But what about elements? For instance, what mass of element A reacts with 1 g of element B? Knowing these numbers could be very useful, but it was hard to relate the equivalent masses to the actual masses of the atoms because they didn't know the formulas. There were two good ways available to figure this out. One was Avogadro's hypothesis based on Gay-Lussac's law, which allowed chemists to relate the equivalent masses to equivalent volumes. The other was Faraday's law, which measured masses of elements produced by a set amount of current. However, Berzelius, who was working hardest on this problem, didn't believe either Avogadro or Faraday.

Berzelius' beliefs held up the progress of science for about 50 years. Eventually, Cannizzaro revived Avogadro's hypothesis at a big meeting of chemists in 1860. His paper explaining how to calculate molecular weights was distributed to everyone, including Julius Lothar Meyer, who wrote that when he read it "doubts disappeared and a feeling of quiet certainty took their place". Avogadro's hypothesis let chemists figure out atomic weights and formulas together. Once Cannizzaro convinced most chemists to accept it, chemists were able to study the actual atomic weights and formulas.

Scientists soon observed patterns in the **valence** of the different elements. Valence is the number of connections an atom tends to form. H is defined to have a valence of 1. For instance:

- methane, CH_4: carbon atoms have a valence of 4
- water, H_2O: oxygen has a valence of 2
- lithium oxide, Li_2O: lithium has a valence of 1
- hydrogen sulfide, H_2S: sulfur has a valence of 2
- aluminum oxide, Al_2O_3: aluminum has a valence of 3

By the 1860s, ~60 elements were known. Using Cannizzaro's atomic weights, Mendeleev and Lothar Meyer made a great discovery, the periodic law: If you arrange the elements by their atomic weights, there is a periodic repetition in properties such as valence. The modern version of this periodic arrangement is the Periodic Table.

Also, within a group (sharing a valence) properties like density, boiling point, heat capacity, etc follow a simple progression. Mendeleev used this to predict the properties of undiscovered elements.

Here's a smaller version of the periodic table that leaves out the elements Mendeleev and Meyer found most problematic (transition metals, rare earths) and the group that hadn't been discovered yet (noble gases). Notice how the the valences repeat every 7 elements when they are arranged according to atomic mass.

Partial Periodic Table

Valence	1	2	3	4	3	2	1
Period							
1							H 1.008
2	Li 6.94	Be 9.0122	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998
3	Na 22.990	Mg 24.305	Al 26.982	Si 28.085	P 30.974	S 32.06	Cl 35.45
4	K 39.098	Ca 40.078	Ga 69.723	Ge 72.63	As 74.922	Se 78.96	Br 79.904
5	Rb 85.468	Sr 87.62	In 114.82	Sn 118.71	Sb 121.76	Te 127.60	I 126.90

But there were some problems with the table. For instance, tellurium (Te) was clearly a chalcogen, in the oxygen family, and iodine (I) was clearly a halogen, based on their properties, but the weights were wrong. (Check the table!) Mendeleev said that the atomic weights must not have been determined correctly, but they were correct.

Outside Links

- Khan Academy: Groups of the Periodic Table (12 min)
- CrashCourse Chemistry: The Periodic Table (11 min)

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