A "Universal" Approach to the Periodic Table of the Elements

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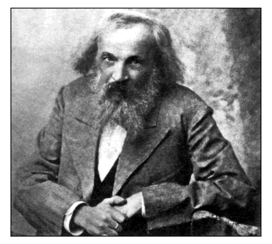
Introduction and Background

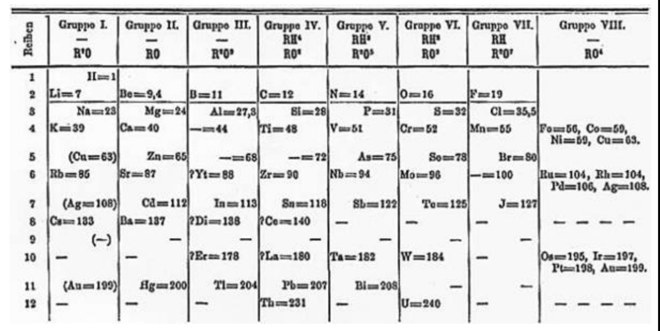
The **Periodic Table of the Elements** is one of the central topics in introductory level chemistry courses. Traditionally, students, at the university level and high-school level, are taught the fundamental theories of atomic models, periodic properties of the elements and quantum chemistry within an historic and/or conceptual perspective that led to the conceptualization of the standard Periodic Table of the Elements. This approach can generate misconceptions and a lack of full comprehensive understanding of the concept of the Periodic Table of the Elements as students sometimes rather memorize the information and concepts only to be repeated at exams. Some students, despite even obtaining high marks in examinations about the Periodic Table, do not fully comprehend it. The following in class assignment/ group work is a hands-on and fun process that explains, **step-by-step**, the intrinsic concepts of Periodic Table of the Elements of "our" universe by comparing it to imaginary, different universes' tables. The "discovery" of these new universes helps the students to understand the fundamental concepts combined in the standard Periodic Table of the Elements and that its contents are based on scientific evidence and are ***not*** arbitrary .

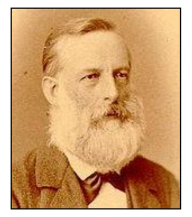
Johann Döbereiner (1780 – 1849)
He put forward his law of triads in 1817 arranging Li, Na, K and Cl, Br, I based on atomic weights.

John Newlands (1837 – 1898)
Newland's Octaves described a repeating property pattern of elements not unlike music notations.

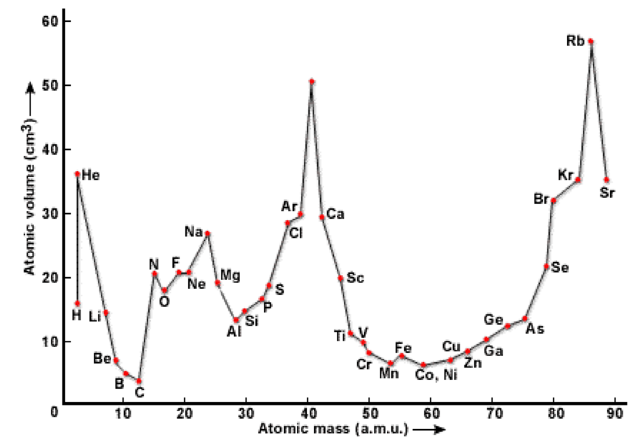


Dmitri Mendeleev (1834 – 1907)
His tabulization of the elements shows the periodic nature of elements' properties and predicted atomic properties of "eka-silicon" (Germanium), a then unknown element, which were close to Germanium's properties.





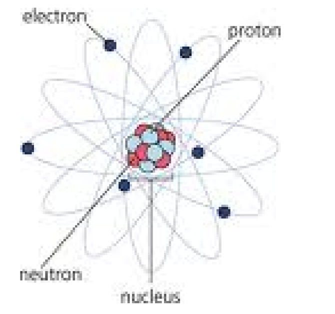
Julius Meyer (1830 – 1895)
Meyer's atomic volume table demonstrated some form of the periodicity nature of the elements.

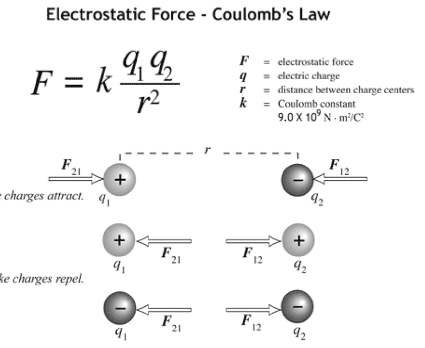


Theoretical Background Information

The students need to be familiar with five fundamental concepts prior to the teaching of the "universal" approach assignments/ group work:

1) **Bohr's Atomic Mode**l: positively charged nucleus is surrounded by negatively charged electrons
2) **Coulomb's Law**: interaction of charged particles
3) **Ionization Energy**: energy required for the removal of electron from neutral atom or ion
4) **Chemical properties of elements depend on electrons and electron arrangement**
5) **Elements are defined by atomic number = number of electrons in neutral atom**





The "Universal" Approach

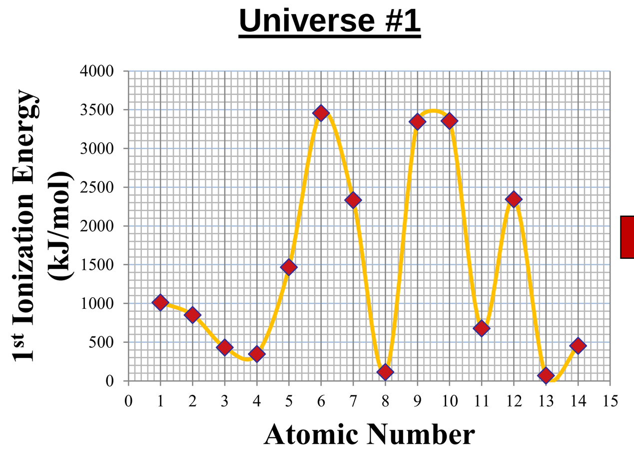
The 2nd year "Introduction to Inorganic Chemistry" class was divided into groups of two students. Each group was assigned to discuss and conclude a Periodic Table based on the given information (i.e. lists of elements and their 1st ionization energies).

Background Story: *"The Starship Inorganic-Breton-Magic has travelled into the epsilon quadrant and has discovered an unusual wormhole that can provide access to undiscovered universes. Captain Bierenstiel has sent out his crew of twelve stellar scientists to gather information about different universes. After sending the crews of two scientists each out for a maximum of 15 min, all return safely to the starship and their exciting results, observations and conclusions are discussed with the whole crew."*

Assumption: All newly discovered universes obey the same physical laws (i.e. Coulomb's Law) as they exist in "our" universe. (Also, the students discovering the different universes are not harmed by entering them. No alien life forms are found – that's exobiology's job.)

Assignment questions:
➔*Draw of a graph with ionization energy (y-axis) vs. element (x-axis).*
➔*What conclusion can be made about the elements and their properties (i.e. atomic radius) in these universes?*
➔*How could the elements be displayed in a logical and comprehensive manner?*
➔*What prediction(s) can be made about additional elements in these universes?*

Universe #1

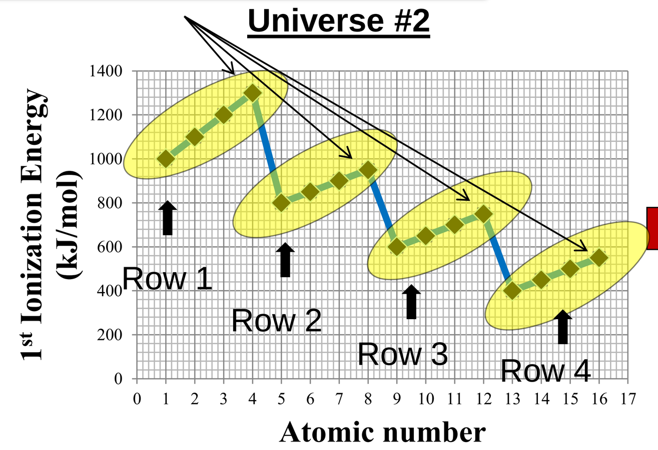


Conclusions:
Random (!) arrangement of ionization energies ➔ no clear trend(s) visible
➔ no predictions possible

Note: *We are actually lucky that "our" universe contains periodicity with elemental properties, albeit some complex. Without periodicity we would need to have individual rules for **every element** and could not group them.*

Universe #2

Relative stable electron configurations due to relative high ionization energies .



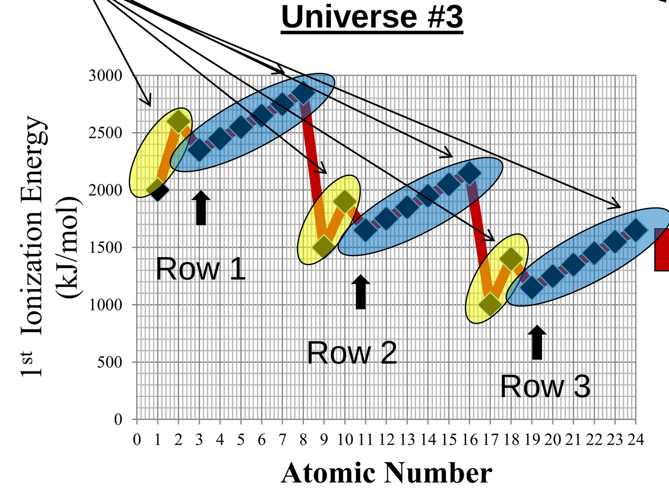
Preferred oxidation states of the elements:
+1 +2 /-2 - 1 0 (=Noble elements)

	I	II	III	IV
Row 1	Aa	Ba	Ca	Da
Row 2	Ea	Fa	Ga	Ha
Row 3	Ia	Ja	Ka	La
Row 4	Ma	Na	Oa	Pa

Examples of predicted compounds:
- Da
- Aa_2Ba
- $BaCa_2$
- AaCa

Universe #3

Relative stable electron configurations due to relative high ionization energies .



Preferred oxidation states of the elements:
+1 +2 +1/+3 +2/+4 +3/-3 -2 -1 0

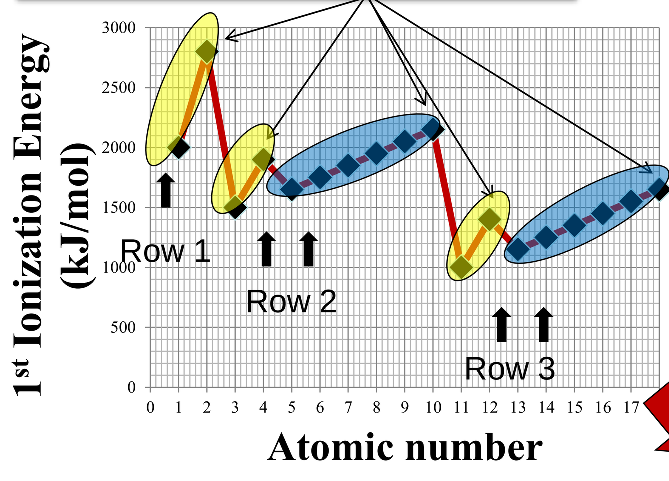
	I	II	III	IV	V	VI	VII	VIII
Row 1	Ab	Bb	Cb	Db	Eb	Fb	Gb	Hb
Row 2	Ib	Jb	Kb	Lb	Mb	Nb	Ob	Pb
Row 3	Qb	Rb	Sb	Tb	Ub	Vb	Wb	Xb

Examples of predicted compounds:
Hb, Ab_2Fb, DbFb, $DbFb_2$, $BbGb_2$, $EbGb_3$,EbFb

The "Universal" Approach cont'd

Universe #4

Relative stable electron configurations due to relative high ionization energies .



Examples of predicted compounds:
Bc, Ac_2Hc, DcHc, $DcIc_2$, $FcHc_2$, $EcIc_3$,GcHc

2 possible ways of tabulating the elements

+1 +2 +1/+3 +2/+4 +3/-3 -2 -1 0

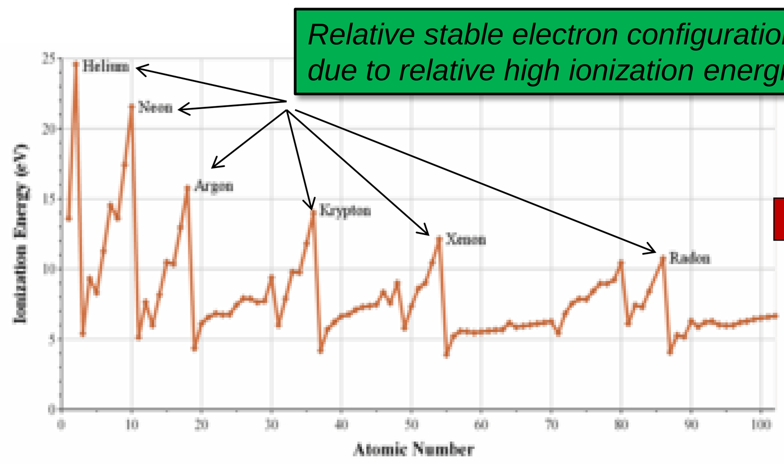
	I	II	III	IV	V	VI	VII	VIII
Row 1	Ac	Bc						
Row 2	Cc	Dc	Ec	Fc	Gc	Hc	Ic	Jc
Row 3	Kc	Lc	Mc	Nc	Oc	Pc	Qc	Rc

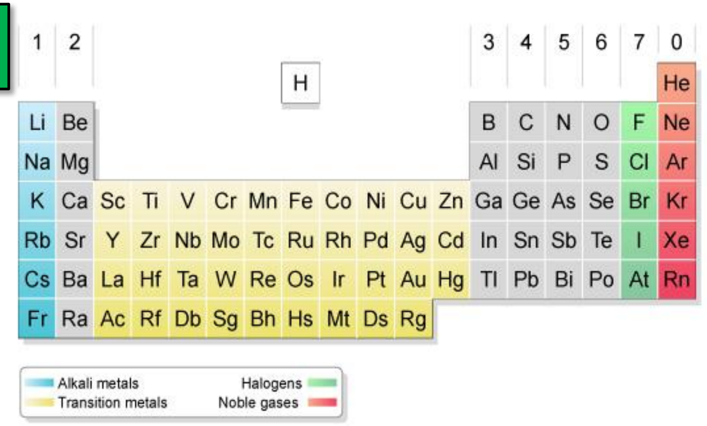
+1 +2 +1/+3 +2/+4 +3/-3 -2 -1 0

	I	II	III	IV	V	VI	VII	VIII
Row 1	Ac							Bc
Row 2	Cc	Dc	Ec	Fc	Gc	Hc	Ic	Jc
Row 3	Kc	Lc	Mc	Nc	Oc	Pc	Qc	Rc

Universe #5 ("Our" universe)

Relative stable electron configurations due to relative high ionization energies .





Conclusions, Current and Future Work

The star ship story to the "universal" approach for teaching of the Periodic Table of the Elements provides a fun factor; students really enjoyed it. The complete assignment set is not been presented here due to space limitation; new "universes" can be made as much complex as necessary and tailored to high-light patterns in the standard Periodic Table; e.g. conflict to standard quantum chemical rules (Hund's rule and Pauli's exclusion principle) can be visualized with an odd number of rows. **The playful attempt of the building-up the Periodic Table from simple, very periodic "universes" to the standard Periodic Table of the Elements provides comprehension for the students as pure memorization of facts does not help in the explanation of the various scenarios.**

This poster presentation is based on the results and feedback of a class assignment in 2nd year inorganic chemistry class– a qualitative and quantitative scientific assessment for evidence of teaching effectiveness was tested with 1st year General Chemistry students.

Alternatively, the "reverse" assignment can be designed by providing new periodic tables. Students are asked to provide ionization energy graphs and examples of predicted compounds.

Universe #6

	I	II	III	IV
Row 1	Ad			
Row 2	Bd	Cd		
Row 3	Dd	Ed	Fd	
Row 4	Gd	Hd	Id	Jd

Universe #7

	I	II	III	IV	V
Row 1	Ae	Be	Ce	De	Fe
Row 2	Ge	He	Ie	Je	Ke
Row 3	Le	Me	Ne	Oe	Pe
Row 4	Qe	Re	Se	Te	Ue