CH1101 : Elements of Chemistry

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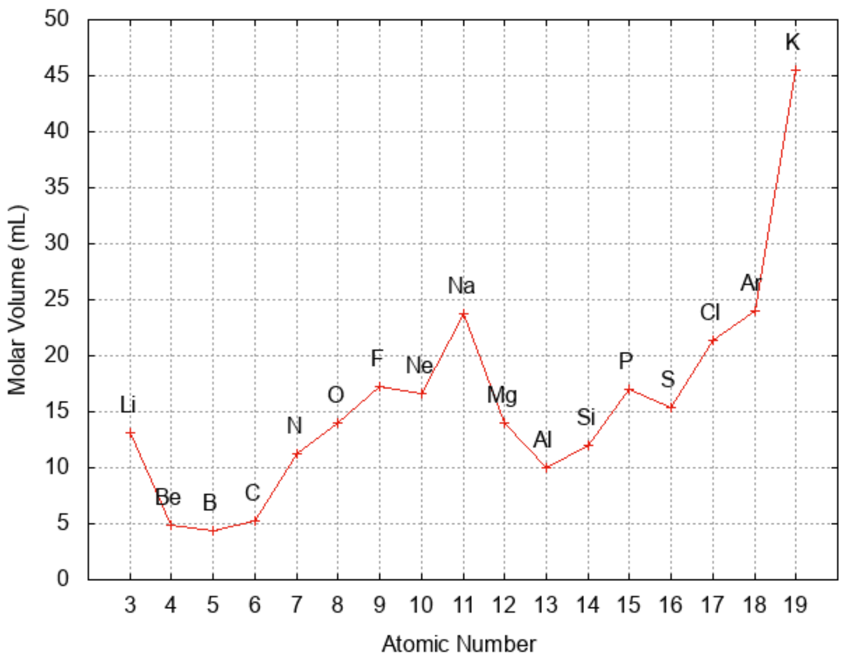
1. Listing the elements in ascending order of atomic weights, we observe a periodicity of 5 (with some gaps) in their physical states, electrical conductivities and chemical reactivities.

Bh^{2}	Ik^{5}	Uc^{6}	Dt^{8}	Bc^{11}
Ai^{14}	Ye^{15}	Sk^{17}	$\mathbf{X}^{\sim 19}$	On^{20}
$\mathbf{E}^{23}$	Zw^{28}	Dr^{30}	Fq^{32}	Fn^{36}

We may conclude that the element E^{23} may be a gas with very low electrical conductivity and very low chemical reactivity.

Similarly, we may predict the existence of a new element X having an atomic weight in the range $17 - 20$, which may be a hard, high melting solid with very high electrical conductivity and high chemical reactivity.

2. We will use the relation $V_m = M/\rho$ between the the molar volume V_m, the molar mass M and the density ρ.



We observe that the molar volume has a general upward trend. It peaks sharply at Li, Na, K (Group 1), and has valleys at B, Al (Group 3).

3. The power of Mendeleev's periodic table lies in its predictive nature. Seeing the gaps in his table, Mendeleev predicted the existence of new elements, such as 'eka-boron', 'eka-aluminium' and 'eka-silicon', along with their physical and chemical properties with stunning accuracy. He was also able to correct inaccuracies in the then known atomic weights of elements using this device.

4. We will use $c = f\lambda$ and $E = hf$.

Frequency f	**Wavelength** λ	**Energy** E	**Event**
3.8×10^{14} Hz	7.9×10^{-7} m	2.5×10^{-19} J	Heating food (infrared)
5.0×10^{14} Hz	6.0×10^{-7} m	3.3×10^{-19} J	Reading (visible light)
3.0×10^{11} Hz	1.0×10^{-3} m	2.0×10^{-22} J	Making popcorn (microwave)
1.2×10^{17} Hz	2.5×10^{-9} m	7.9×10^{-17} J	Dental (X-ray)

5. We will use $\lambda = h/p$, $p = mv$. An O_2 molecule weighs 32 amu $\approx 5.3 \times 10^{-26}$ kg. Thus, its momentum is 2.5×10^{-23} kg m/s, and its de Broglie wavelength is 2.6×10^{-11}m = 26 pm. Clearly, this is a small fraction (10.7 %) of the molecular length of O_2.

6. A UV photon will obey the relation $E = hc/\lambda$.

   (a) Each photon has an energy of $E = 4990$ kJ$/N_A \approx 8.3 \times 10^{-18}$ J. Thus, we have $\lambda = hc/E \approx$ 24 nm.

   (b) A 500 nm photon will have an energy of $hc/\lambda \approx 4.0 \times 10^{-19}$ J. 21 such photons would have an energy just exceeding that of a UV photon.

   (c) Although 25 such photons carry a total energy more than that of a single UV photon, they cannot induce mutation in a strand of DNA. This is because exactly the right amount of energy must be supplied to the $\pi-$bond in a thymine base in DNA for it to break, and thus mutate. The breaking of such a bond involves the absorption of the photon by an electron in a bonding molecular orbital, promoting it to an antibonding orbital. Such a promotion requires just the right amount of energy – the energy difference between the two orbitals.