ACTIVITY 3 – ATOMS AND THEIR MASSES

Background Information

Historical

In the early 1800s an English scientist, John Dalton, worked on the Grecian concept that all things can be broken down into atoms. He assumed that if atoms really exist then these atoms should have unique properties. Dalton's Atomic Theory was based on his observations and he developed the following postulates:

- Matter consists of small particles called atoms.
- The atoms cannot be destroyed. In chemical reactions, the atoms rearrange but they do not themselves break apart.
- All atoms of the same element have the same properties and identical masses.
- Atoms of different elements have different properties and masses.
- When atoms of one element combine with the atoms of another element, they always combine in the same proportional ratio.

The law supported an observation that scientists had already made; the Law of Chemical Composition. The theory's postulate also supported the Law of Conservation of Mass and The Law of Multiple Proportions could also be explained from Dalton's theory.

Relative Masses of Atoms

We have no instrument sensitive enough to measure the mass of a single atom. We can, however, arbitrarily assign a mass to one atom and determine the masses of other elements relative to it. If we assign a mass of 12 atomic mass units (amu, or daltons) to pure carbon-12, we find that the mass of carbon atoms is 12 times that of the mass of hydrogen atoms. We can then assign the mass of hydrogen as 1 amu. When examining water, (with the knowledge that there are two hydrogen atoms for every oxygen atom) we get a value of 16 amu for the mass of oxygen. With the knowledge of combining ratios in compounds using the laws described above, early chemists were able to establish relative atomic masses for many elements.

Displacement Reactions

One of the major classes of chemical reactions is the **displacement** reaction. This type of reaction has the same number of reactants as products and occurs when an atom in a compound is displaced by another atom. Single-displacement reactions can be represented as:

$$A + BC \longrightarrow AB + C$$

One interesting thing about these reactions is that different metals have different reactivities. They can be ranked according to their ability to displace other metals from various compounds or to displace one another from solution. The activity series of the metals arranges them in order of decreasing reactivity as a reducing agent.

Activity Series of the Metals

Li K Ba Ca Na Mg Al Mn Zn Cr Fe Cd Co Ni Sn Pb Cu Hg Ag Au

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Decreasing strength as reducing agent

The overall single-displacement reaction used in the activity is shown below. Note that because Al comes higher on the activity scale, it displaces Cu easily. We also note that the atoms are conserved and the mass is conserved. When we talk about the conservation of mass we assume that we are dealing with the element's naturally occurring isotopes and that they are not altered in the reaction.

Overall reaction:

$$2Al(s) + 3CuCl_2(aq) \longrightarrow 3Cu(s) + 2AlCl_3(aq)$$

Total ionic equation:

$$2Al(s) + 3Cu^{2+}(aq) + 6Cl^{-}(aq) \longrightarrow 3Cu(s) + 2Al^{3+}(aq) + 6Cl^{-}(aq)$$

The Cl ions remain unchanged on both sides of the equation (thus they are called *spectator ions*), and can be removed to express the net ionic equation.

Net ionic equation:

$$2Al(s) + 3Cu^{2+}(aq) \longrightarrow 3Cu(s) + 2Al^{3+}(aq)$$

Then 0.2 g of aluminum would theoretically produce 0.7 g of copper.

Note that in the overall reaction the oxidation number of uncombined aluminum is zero. After the reaction the aluminum has an oxidation number of 3+. Its oxidation number has increased, so we say it has been **oxidized**. Nothing can be oxidized unless something else is simultaneously reduced. The copper as a reactant has an oxidation number of 2+, and as a product its oxidation number is zero. Its oxidation number has decreased, so we say it has been **reduced**. The reduction was caused by the aluminum, so Al is the reducing agent. The charges as well as the number of atoms on both sides of the equation are balanced.