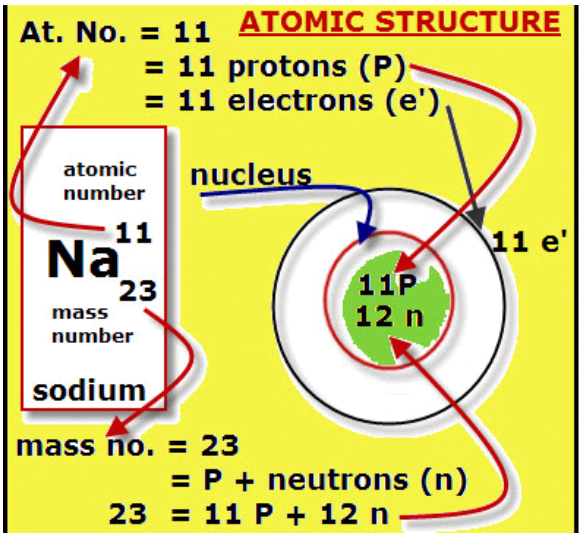
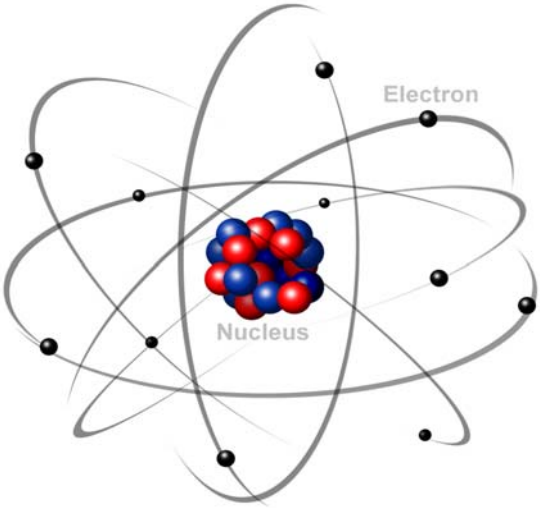
STATION 16 - Chemical Reactions

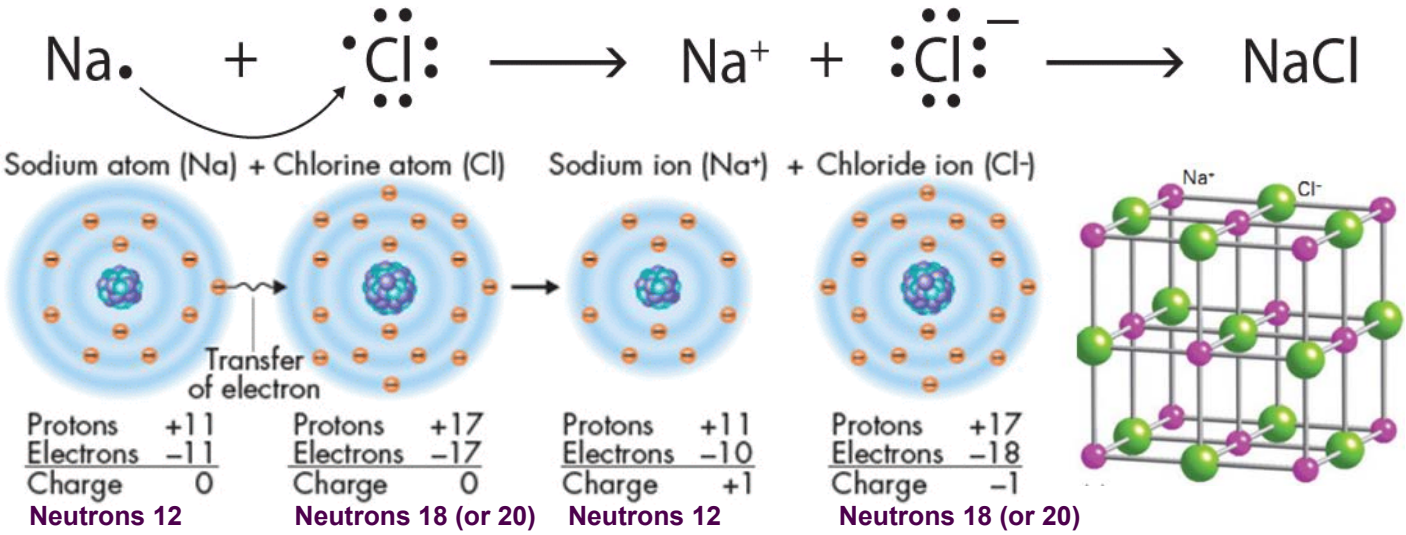
Chemistry is often called the central science. At the heart of chemistry are the reactions that convert one substance into another. What changes in chemical reactions. To understand this concept, it is helpful to examine an atom. Atoms are composed of a small nucleus consisting of protons and neutrons surrounded by a cloud of electrons. The periodic chart is arranged according to the number of protons in the nucleus (the atomic number) and starts at 1 for hydrogen and goes up to 92 for uranium, the last naturally occurring element and up to 118 for elements synthesized using nuclear methods in the laboratory. The neutral atom also has an equal number of electrons. The number of neutrons for each element is slightly variable (isotopes) but is approximately equal to the number of protons for the light elements and then increases to about a 1.6 ratio of neutrons to protons for very heavy elements. The number of neutrons has little effect on the chemistry of the element but does play a very important role in the nuclear stability of the atom. For more information on nuclear stability, please see Station 17.





For example, the atomic number of sodium (Na) is 11. A Na atom has 11 protons and 11 electrons. The only naturally occurring isotope of Na has a mass number of 23 and 12 (23 - 11) neutrons. The model for Na (left) is oversimplified.

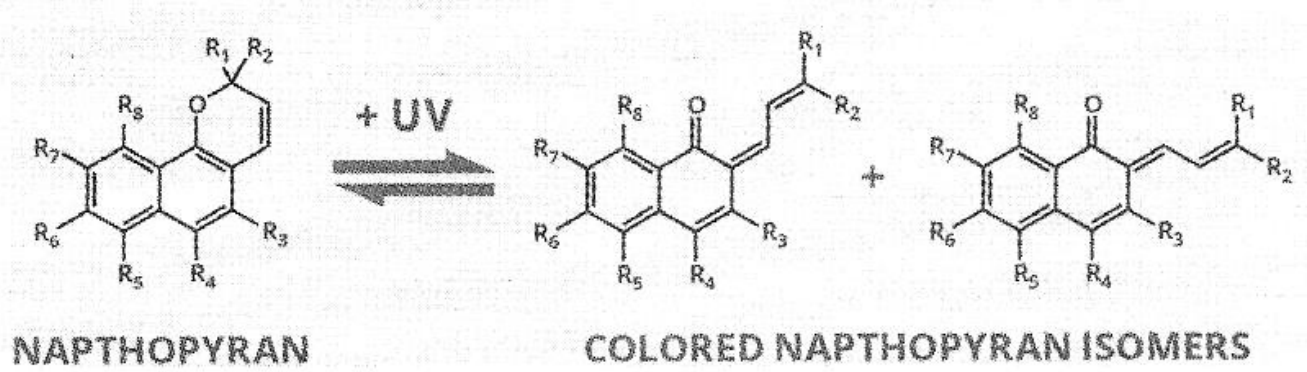
Chemical reactions are the result of the gain or loss of electrons or bonding changes (involve electrons only). The nucleus does not change in a chemical reaction. When a sodium atom reacts with chlorine atom [chlorine like many gases exists in nature as a diatomic molecule (Cl_2) but for simplicity, a chlorine atom will be used to demonstrate the reaction], an electron is transferred from the sodium ion to the chlorine atom. A sodium ion with a positive charge (cation) results that is strongly attracted to the now negatively charged chloride ion (anion). An ionic bond holds the sodium cation and chlorine anion strongly together (again this is an oversimplification as in a sodium chloride crystal, each sodium is surrounded by 6 chlorides and vice versa).



[Note: Chlorine has two natually occurring isotopes - 76% have 18 neutrons and 24% have 20 neutrons.]

In summary, chemical reactions are the result of the gain or loss of electrons yielding ionic bonds, the sharing of electrons yielding covalent bonds or the exchange of ionic partners. To illustrate chemical reactions in a museum exhibit presents challenges as chemicals need to be continually replenished and there are significant disposal issues. For this reason, reversible reactions are used in this station (photochromism) and in Station 19 (thermochromism).

Station 16 demonstrates a type of chemical reaction called photochromism. Ultraviolet (UV) light is a form of energy that is in the range of chemical bond energies. A UV light will be used to cause a chemical reaction in compounds in plastic beads. This particular reaction is reversible and the photochemical products should revert to the starting materials in the absence of UV light.



Are your observations consistent with the comments above?

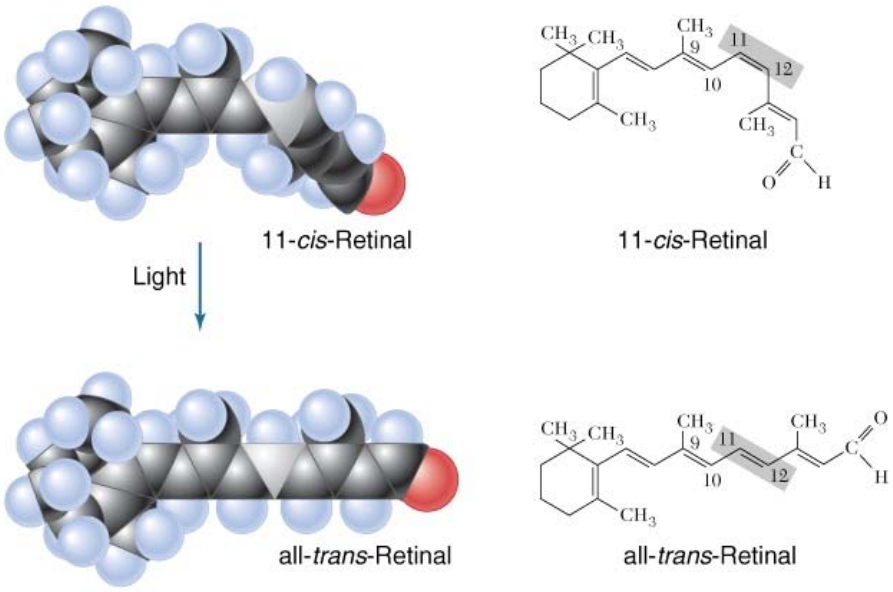
Concepts and Answer

In the medical field, one common approach has been to test for activity for some kind of application (such as antibiotic properties) with all chemicals available. When a compound with activity is discovered, the compound is tested for toxicity and effectiveness. This is a very time consuming and expensive procedure. Unfortunately, despite having effective properties, many compounds with useful activity have undesired side effects and are not effective enough. As you will observe in Station 18, penicillin G fell into this category but synthetic organic chemists were able to use chemical principles to design improved structures with fewer side effects and improved effectiveness. Today, it has become possible to use computers to design compounds with appropriate activity. Organic chemists then devise methods to synthesize these compounds to enable testing.

Since chemical synthesis is the heart of chemistry and this exhibit focuses on chemistry, inclusion of a chemical reaction into the exhibit seemed appropriate and perhaps necessary. For the purposes of this exhibit, having visitors perform chemical reactions would be expensive and require the additional expense of disposal the products. To avoid these issues, a search for an easily observed reversible chemical reaction was performed. As a result, you are about to perform a reversible photochromic reaction.

Energy is involved in all chemical reactions. Endothermic reactions require energy input to convert reactants to products. Exothermic reactions give off energy along with the production of chemical products. Light is a form of energy and depending on the wavelength is comparable in energy to the bond strengths of many bonds. In other words, if light energy can be localized at a desired reaction site, the light contains sufficient energy to break many types of bonds. In photochromic reactions, the light causes an observable chemical reaction (e.g., the darkening of sun glasses) but produces a product that thermally reverts back to the original compound after a relatively short time.

You should be able to notice that as the photochromic beads go under the UV lamp, their color changes from off white to other colors commonly purple. A typical photochromic reaction is shown on the station poster. After the absorption of light (a photon), bonds break and the chemical changes from a colorless molecule to a colored one. Once the compound is out of the lamp focus, the reaction reverses and the colorless molecule is reformed. Please not that most photochemical reactions are not so easily reversible and the product is often stable. One example is the absorption of light in your eye that is enabling you to see this writing.



Materials and Images. Photochromic beads are available from many sources including Educational Innovations and Ebay.
https://www.amazon.com/dp/B00K763UIG/ref=pd_lpo_sbs_dp_ss_1?pf_rd_p=1944687562&pf_rd_s=lpo-top-stripe-1&pf_rd_t=201&pf_rd_i=B00JXGHGTA&pf_rd_m=ATVPDKIKX0DER&pf_rd_r=6CVX0RS83V5V0MAMFGZQ