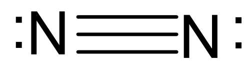
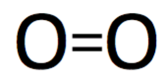
STATION 18

MOLECULAR MODELS OF SOME SMALL MOLECULES AND PENICILLINS

Find the molecular model for each of the chemicals discussed below.

Nitrogen is 78% of the content of our atmosphere. It exists as a diatomic molecule (N_2) and is represented by the Lewis structure to the right. Because of the triple bond, it is relatively unreactive. Note that explosives such as TNT contain nitrogen as the reaction of the explosive yields the very stable nitrogen molecule and a huge volume of gas and large amounts of energy.

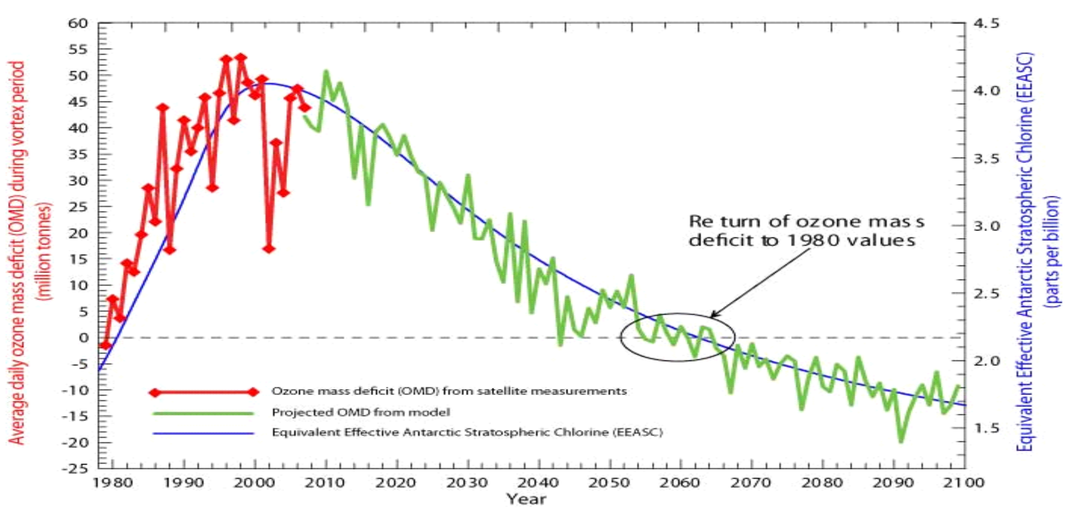


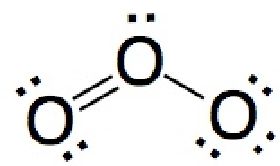


Skeletal structure of O_2.

Oxygen is 21% of the content of our atmosphere. Oxygen exists as a diatomic molecule (O_2) and is represented by the structure to the right (a Lewis structure with the electrons showing is not presented as the model is not consistent with the properties of O_2). There are three formulas of oxygen that can exist - O, O_2 and O_3 (ozone). O and O_3 are very reactive and toxic. It is difficult to imagine a type of life that could exist without O_2. Ozone is produced as a result of combustion processes and is a primary and dangerous constituent of smog.

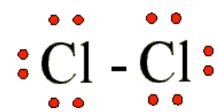
However, O_3 plays a very important role in the upper atmosphere by filtering out substantial amounts of harmful UV radiation. In the 1970's, chemists provided evidence that



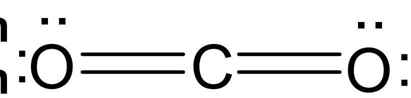


freons used as spray propellants and in air conditioning units were causing a depletion of the very vital ozone layer. Fortunately, global governmental action as substantially decreased the use of the harmful freons and the ozone layer is slowly recovering from it hazardous decrease (lower ozone results in more skin cancer). Many people connect the ozone depletion issue with climate change. However, the issues are not related except that freons do cause both. The global community needs to understand the importance of the precedent set by the global response to the ozone issue and take similar action to remedy the even more serious climate change issue.

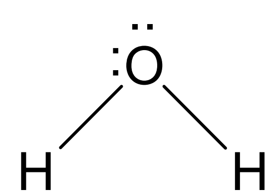
Chlorine is also diatomic (Cl_2) and is highly toxic to life. Its toxicity makes it very useful in water purification.

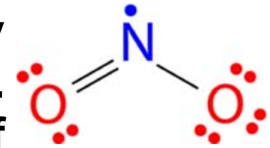


Carbon dioxide (CO_2) is a linear molecule that comprises 0.04% of the content of our atmosphere. CO_2 is fairly unreactive chemically and is used to extinguish fires. As discussed in Stations 19 and 20, human use of fossil fuels has increased the CO_2 content of the Earth's atmosphere by 44%. This increase is causing an increase in global temperatures with rising sea levels and ice mass loss and is a severe threat to life and our environment.

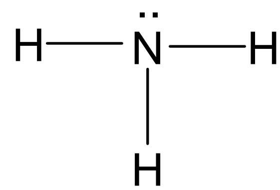


Water (H_2O) is a bent polar molecule that is probably essential for life anywhere. Because it is bent and has polar bonds, polar molecules like NaCl and sugars will dissolve in water but non-polar molecules like CO_2 have very limited solubility in water and escape from carbonated beverages when the container top is removed.

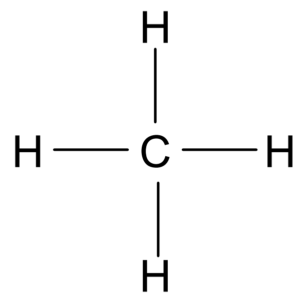




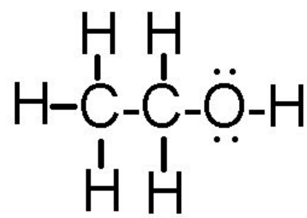
Nitrogen Dioxide (NO_2) is an orange gas that is a very irritating and dangerous component of smog. NO_2 is often formed from further oxidation of NO that results from combustion processes such as combustion in the automobile's internal combustion engine. NO_2 is removed from the emissions by a catalytic converter. Notice that NO_2 has an unpaired electron which makes NO_2 a very reactive free radical.



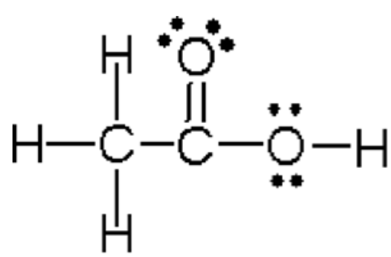
Ammonia (NH_3) is a base (reacts with acid) with an annoying odor. NH_3 is important in the penicillin discussion that follows.



Methane (CH_4) is the major component of natural gas but is also a potent Greenhouse gas. As a result of pipeline leaks, fracking carelessness and other sources, the atmospheric CH_4 concentration is increasing and significantly contributing to global warming.



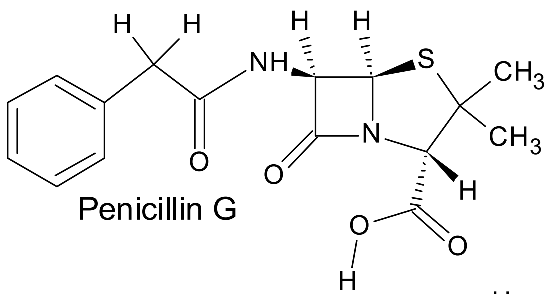
Ethanol (a.k.a. ethyl alcohol or sometime just alcohol - CH_3CH_3OH) is a member of the class of organic compounds called alcohols. Alcohols have an OH group attached to a carbon bonded to three additional atoms (usually C or H). Small alcohols have some properties similar to those of water. Ethanol is the alcohol in alcoholic beverages.



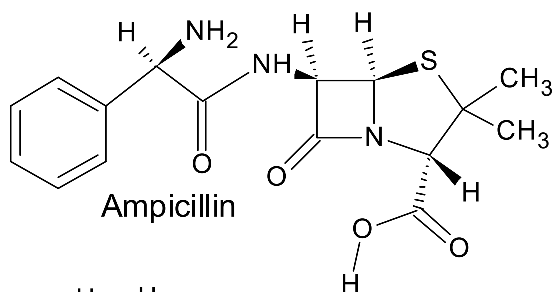
Acetic acid (CH_3COOH) is the active component of vinegar (about 5%) and is form from air oxidation of ethanol. Opened bottles of alcoholic beverages acquire a vinegar taste if left standing open to the air for too long.

PENICILLINS

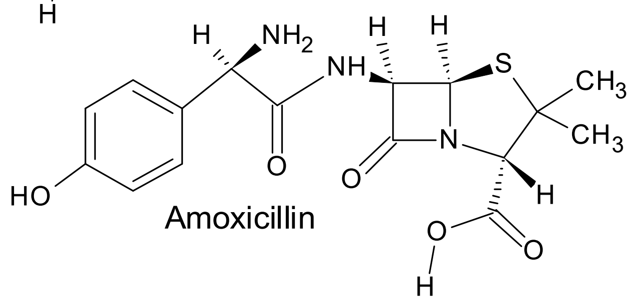
In 1928, Alexander Fleming serendipitously discovered penicillin g. As penicillin G is unstable in stomach acid, it cannot be taken orally and had to be delivered with an injection. Some brilliant and what appears to be simple chemistry (actually very difficult and time consuming) was performed to convert penicillin into ampicillin. Ampicillin is stable in the stomach acid and can be administered orally. Ampicillin has been slightly modified to make one of the most common antibiotics still in use today called amoxicillin. Examine the molecular models and the structures below and determine the differences between penicillin G, ampicillin and amoxicillin.



Penicillin G



Ampicillin



Amoxicillin

1. Describe the differences between each of the penicillins.

2. The ammonia molecule (NH_3) is a base and reacts with hydrochloric acid to give a stable ammonium chloride salt. Does this give you any information about why the change from penicillin G to ampicillin and amoxicillin made them stable in the stomach?

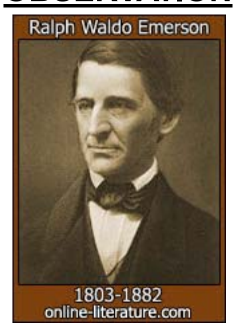
Concepts and Answers

The scientific method is usually described as consisting of five steps:

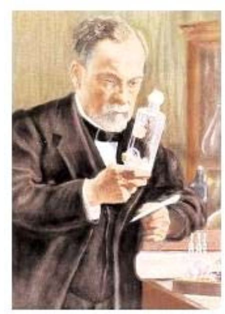
1. observation (including questions about the unexpected, notice)
2. hypothesis (an explanation for the observation
3. testing (to determine if the hypothesis is correct)
4. elevation to theory level (testing is consistent with the hypothesis and the concept is useful for predictions)
5. application, testing and improvement (or replacement) of the theory

The key to good science is the ability to make careful, complete and unbiased observations. Often observations that might not seem important are those that lead to significant discoveries. Rubber, artificial sweeteners, teflon and penicillin are examples of chance discoveries that were not overlooked but were pursued and developed. Please note the following quotations about the importance of careful observations.

SCIENCE
&
OBSERVATION



In the field of observation, chance favors only the mind that is prepared.
Louis Pasteur

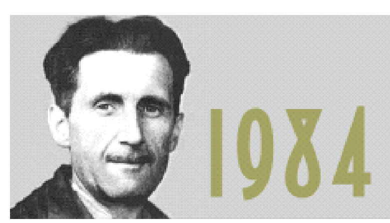


God hides things by putting them near us. Ralph Waldo Emerson

To acquire knowledge, one must study; but to acquire wisdom, one must observe.
Marilyn Vos Savant

You are one of the rare people who can separate your observation from your perception...you see what is, where most people see what they expect.
Tsitsi Dangarembga

To see what is in front of one's nose needs a constant struggle.
George Orwell



Examination of the structures of penicillin G, ampicillin and amoxicillin reveals that the primary difference between penicillin G and the other two is that ampicillin and amoxicillin contain an NH_2 group. The NH_2 group, like ammonia (NH_3) is a base and reacts with acid as follows:

$HCl(aq) + NH_3(aq) = NH_4Cl(aq)$
$HCl(aq) + RNH_2(aq) = NRH_3Cl(aq)$

In the approach used for penicillin G, a compound that had remarkable and useful properties, the goal was to improve its acid stability. Chemists used very simple chemical principles to incorporate acid stability into the basic penicillin structure. Ammonia is a base and reacts with acid to form a salt. Knowing this, chemists were able to find a way to add part of the ammonia molecule into penicillin. With this $-NH_2$ in the structure, the ampicillin reacts with acid to form a salt that is stable in the stomach and that can subsequently be absorbed into the body and kill bacteria. However, in doing so, it was possible that a structural change would decrease or eliminate its antibiotic properties. Fortunately, this was not the case and ampicillin and amoxicillin are actually better antibiotics than penicillin G. The downside is that antibiotics have been overused including for purposes such as fattening animals for slaughter. This overuse has led to resistance buildup by bacteria. We are now entering a new era where bacteria might once again become effective killers. We need to use antibiotics only when needed and search for new antibiotics that can kill resistant bacteria.