Introduction

One of the first things to do when you approach a new field is to get familiar with the terminology people in the field use. As you start this chemistry course, you need to learn m to use the terms that chemists use. Since chemistry is a science, that means you need to learn to talk and think like a scientist.

If this is **not** your first science course, much of the material in this note pack will be a review. Even so, read through it anyway. Science is a group effort, and it's vitally important that we use the same words to describe the same things when we're doing science.

Science and the scientific method

You can simply define science itself as the systematic study of the natural world. But that definition is missing something. The **way** that knowledge is obtained is a vital part of science. Scientists use something called the **scientific method** to gain knowledge.

The scientific method is shown on the flowchart in Illustration 1. We start with observation or information-gathering. We observe and document something that is happening. Once we've gathered enough information, we try to **explain** what is happening - we create what scientists call a **hypothesis**.

A hypothesis is an **explanation** of the thing we are observing. It tells us why (we think) the thing is happening, and gives us a direction for future research.

After we develop a hypothesis, we don't just sit back and congratulate ourselves on a job well done. Good hypotheses make **predictions** that can be tested. (Many scientists will tell you that if there's no way to test something, then that something isn't science!) So we do further experiments - giving ourselves more observations to compare to our hypothesis.

We also deliberately try to **falsify** our hypothesis - by setting up tests where we can evaluate whether the hypothesis accurately explains what we think it does.

After that, we tell other scientists about our hypothesis, so **they** can try to come up with ways to break it. It sounds stressful (and can be), but this is the only way we can ensure that we're not fooling ourselves.

So what if there's a problem with our hypothesis - something that doesn't fit into our explanation? Depending on how big the problem is, we can either **modify our hypothesis** or scrap it completely for a new one. Most hypotheses are changed at least a little after they're developed, and there's no shame in admitting that we have had to change our hypothesis based on new evidence.

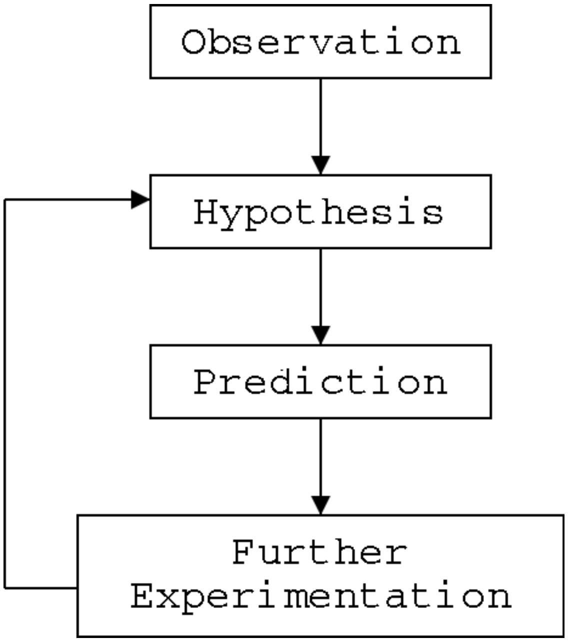

Illustration 1: The scientific method

- The scientific method starts with observations of the real world and attempts to explain them. These observations should be reproducible, since humans can make measurement errors.
- The explanation (the hypothesis) is then tested based on the predictions about similar phenomena that the explanation predicts.
- If the explanation doesn't predict the results of the new experiments, the explanation must be modified or (if it's too far off the mark) rejected.
- Don't think of the scientific method as a **list** of things to do. Think of it as **an ongoing process**!

Terminology: hypotheses, theories, and laws

In everyday language, a "theory" is the name given to a conjecture or a guess. A "law", in everyday language, is something that's always true, and nobody outside of science routinely uses the word "hypothesis".

Unfortunately, science uses all three of these terms, and the meaning of these terms to scientists is **very different** from the common meaning. This leads to quite a bit of confusion when people with no scientific training at all look into science without realizing the terminology differences.

In science, the word that's closest to "conjecture" or "guess" is **hypothesis**. A hypothesis is an explanation of something that's so far supported by only a small set of data. It's quite common for a hypothesis to either need revision or be scrapped entirely for a better idea.

The **theory**, on the other hand, is **also** an explanation of something. However, it is an explanation that has been tested, revised, and retested until most scientists regard it as the best explanation available for the something in question. That's a point worth restating; **a scientific theory is the best currently available explanation of data**. That's not so say that scientific theories are never changed (all explanations in science must agree with new data - else the explanations need revision), but that they don't get changed on a whim. (To put it another way: if you are able to gather good data that overturns a well-established scientific theory, you will earn yourself a place in the history books.)

That leaves us with **law**. Unlike bills in Congress, theories do not get promoted to laws when they're signed by the President of Science! **Laws** in science are simply **descriptions** of some regularity in nature. Often these are given as equations, such as the well-known **law of gravity**.

Laws are also not necessarily always true; they often have well-defined limitations. In chemistry, a simple equation called the **ideal gas law** describes how the volume of a gas relates to the pressure and temperature. But the ideal gas law is limited to conditions well away from the pressure and temperature at which the gas would change to the liquid state. The ideal gas law fails to give correct volumes at these conditions.

A key difference between laws and theories is that laws do not **explain** anything. They merely **describe** a phenomenon. Explanations are left to theories. The ideal gas law does not explain why the volume of a gas depends on pressure and temperature. The explanation of gas behavior is contained in **kinetic theory**, which (along with the ideal gas law) will be discussed later in this course.

<u>An example of the scientific method: combustion</u>

Let's say you were a scientist back in the old days who was interested in combustion. When you burn a material like wood, you get ash. If you look at the ash, it appears smaller than the original wood. If you weigh the ash, you notice that the ash is much l**ighter** than the original wood. You try to burn some other substances - some burn and some don't. Of the ones that burned (leaves, paper, hair, meat, etc.), you notice that, like wood, the remaining ash appears smaller and weighs less than the original material.

From these observations, you'd probably conclude that the process of burning releases something from the material that was burned. Materials that burn (combustibles) must contain this substance, while noncombustibles don't. The lost weight would be evidence of the substance's presence in the original material.

This explanation is a scientific hypothesis - an explanation of some of the features of combustion. One prediction that comes from this hypothesis is that the ash of a burned material should always weigh less than the unburned material.

So, you conduct more experiments, and eventually start burning some of the more easily combustible **metals** like calcium or magnesium. Although the ash from these metals **appears** similar to the ash from the earlier materials, you find that it weighs **more** than the original metal does - every time.

Going back and looking at your earlier experiments, collecting both the ash **and** the gases released by the burning wood shows you that the metals aren't really an anomaly. The combined weight of the gases and the ash is actually larger than the original weight of the wood. You find the same to be true for the other substances you had burned.

You notice that the data now points in a different direction from your original hypothesis. Combustion must be the **combination** of a substance with the combustible material, not the **loss** of a substance already contained in the material. Using this new hypothesis, you might set out to identify what this material was, and you're off to do more science!

This little example is a simplified version of what **did** happen around 1800, when the **phlogiston theory** (which held that combustion was caused by the loss of a substance called "phlogiston" from a combustible) was replaced by the modern theory of combustion - that burning was the combination of a substance with oxygen gas.

Summary

This note pack gives you a basic introduction to the scientific method and the terms used by scientists to describe their work. You should be familiar with the steps of the scientific method and the terms hypothesis, theory, and law.