Appendix A

STSE

Important Notes

1. These STSE modules are intended for teacher reference. Each is designed to target specific outcomes within Science 3200. It should be noted that the activities associated with each module are NOT mandatory. They are suggested activities to be used at the discretion of the teacher.
2. These STSE modules and the associated supplements can be found at www.gov.nl.ca/edu/science_ret/sp/sci3200.htm

1-1 What in the World is Chemistry

Outcomes:

1. Provide examples of how science and technology are an integral part of our lives and our community. (117-5)
2. Identify new questions and problems that arise from what was learned. (210-16)
3. Identify and describe science and technology-based careers related to the study of chemistry. (117-1)

Where Can I Find Examples of Chemistry in the 'Real World'?

When studying chemistry, it's easy to get caught up in all of the chemical symbols, the unfamiliar lab tools and chemical reactions which do not seem to be related to the real world. If you are starting to wonder "Where in the 'Real World' will I find chemistry?" then this module will help you find the answer to that question.

1. Remember "Teflon®"?

Teflon®, the chemical which the Guinness Book of Records calls "the slipperiest substance known to man." Not only is it slippery, when a substance is coated with Teflon® it also becomes waterproof. These days, Teflon® is used in a huge number of products whenever a slippery, waterproof coating is needed. The most common place to find Teflon® in the house is a non-stick frying pan, yet it's probably in several other household items. Winter clothing often contains Teflon® to make cloth waterproof without making the cloth too heavy. Shirts and pants often contain a thin coating of Teflon® to make them 'spill resistant.' Some wall paint contains Teflon® too[1]. When the paint dries, the Teflon® is spread through the paint, making a slippery finish which is a lot easier to clean than other paints.

Teflon® is just one example of a chemical that seems to 'pop up' in many different places where you probably thought that chemistry wasn't involved. Let's check out some more places where chemistry is at work every day.

2. Hair Colour Chemistry

People have been dying their hair for thousands of years. The ancient Egyptians had recipes for using juniper berries to dye hair found in the scrolls of the pyramids.[5] The very first hair dye for sale was put forward in 1907 by "The French Harmless Hair Dye Company," which went on to become the company known as "L'Oréal" today.[6]

Figure 1. applying hair foils

As you can tell from the name of the first hair dye company, hair dying is something that has to be done safely and with some thought of the chemicals involved. While there are hundreds of hair dye products on the market these days, we'll touch on a few of the common chemicals involved in hair dye here.

Let's start with a classic product for guys: Grecian Formula®. This product has been around for years as the classic men's product to get rid of grey hair for "that natural look." The active chemicals in Grecian Formula® are sulfur, S_8, and lead(II) acetate, $Pb(CH_3COO)_2$.[7] The way this product works is as follows: the Grecian Formula® solution is rubbed on the hair, and it penetrates the grey hair's root. The lead(II) acetate reacts with sulfur atoms (either in the solution or the natural sulfur in the hair's proteins) to form lead(II) sulfide (PbS). Lead(II) sulfide has a very dark colour, so the grey hair becomes coloured with this compound.[6]

Figure 2. Grecian Formula®

All is well, right? Mr. Grey looks like Mr. Youthful again... but then again... what are the effects of lead ions on natural systems? Is this the safest hair colouring product on the market for men? Is it a coincidence that this is the only hair colouring product on the market with lead ions in it?

As for women's hair dyes, the most popular are permanent dyes, which do not wash out. Permanent dyes often contain two envelopes which are packaged separately and not mixed together until ready to use. One envelope contains a solution of ***ammonia***, ***NH_3***, along with the dye compounds while the other envelope contains ***hydrogen peroxide, H_2O_2***.

The colouring works in the following way:

As soon as the ammonia dye solution and the hydrogen peroxide solution are mixed together, they are rubbed onto the hair. The ammonia in the mixture (less than 1% concentration) causes the each hair strand to swell and "open up" a little, so the colouring can get inside. The hydrogen peroxide serves a couple of purposes. First, the hydrogen peroxide enters the hair, and begins to "oxidize" or "bleach out" the original colour. As this happens, more peroxide reacts with the dye compounds as they enter the hair cuticle. It takes time for the dye to fully react with the peroxide to develop the final colour. This is why even when brown hair coloring is first applied it looks white, and is also why you have to wait a half hour or more for the final color to develop. Once the dyes have fully reacted and have blended in each hair follicle, the final hair colour has developed.[6]

Depending upon what colour is wanted, the dye compounds in the envelope with the ammonia can be adjusted. It is the basic chemistry of ammonia being used to "open up" the hair strand and hydrogen peroxide to "freshly develop" the correct hair dye colour, regardless of your dye colour choice. So now you know how hair dyes work - it's chemistry!

3. From the Beauty Salon to the Hardware Store

We just saw how chemistry is at work at every beauty salon in the province. But chemistry isn't just for the beauty salons - a quick walk through the hardware store can also involve a lot of chemistry. Check out the following.

In the building supplies section, "PVC pipe" is found. It is used in all basic household plumbing. PVC stands for - "**P**oly**v**inyl **C**hloride". Some products just call this "vinyl" and vinyl siding is just a thinner version of the same compound.

In the gardening section, "Bordeaux mixture" is found. It is used in killing fungus and mildew on plants, allowing them to last longer and look better. The mixture contains copper(II) chloride (the main fungus killer) and calcium oxide, a.k.a. "lime."[8]

In the paint section, containers of "TSP" are found. "TSP" is "trisodium phosphate" and is used for cleaning and priming a concrete surface before it is painted.

In the cleaners section, bleach is found. Bleach - such as Javex® - is also found in grocery stores, and is found in everything around the house from clothes stain removers to dishwasher liquids and floor cleaners. “Bleach” is the general term for a solution of ***sodium hypochlorite, NaOCl***, and it is used in more than just inside the house. The “chlorine” that people often talk of in swimming pool water or town tap water is not actually “Cl_2”. It is NaOCl which is bleach.[9]

Bleach is a strong “oxidizing agent”, and in every case listed above, bleach works by “oxidizing” and destroying unwanted bacteria or compounds.

Figure 3. Chlorine in swimming pools is NaOC1, not $C1_2$.[9]

4. It’s all “Alcohol” isn’t it?

The word “alcohol” can refer to many things. Rubbing alcohol has the chemical formula C_3H_7OH. Wood alcohol has the formula CH_3OH, and is found in car windshield wash (especially the winter blend). Alcoholic drinks contain C_2H_5OH.

The table below lists the chemical names of each alcohol above.

Alcohol	***Formula***	***Chemical Name***
wood alcohol	CH_3OH	methanol
alcoholic drinks	C_3H_5OH	ethanol
rubbing alcohol	C_3H_7OH	2-propanol

The table shows some trends. Alcohols all have the group “OH” in their formulae, and never contain any metals. The chemical name of alcohols always contain the “-ol” ending.

Another common alcohol is ethylene glycol, $HOCH_2CH_2OH$. Ethylene glycol is commonly used as car radiator coolant.

If these are all alcohols, why is only ethanol listed in alcoholic drinks? The answer is simple. While they are all alcohols, they do not all have the same effect on the body. We know that alcoholic drinks have the effect of distorting our view of the world and the time it takes to react to movement, but, what do the other alcohols do? Rubbing alcohol is often used as a cleaner or disinfectant - a positive effect. Too bad we can’t say the same thing for methanol or ethylene glycol, since both have big-time nasty effects. Simply put, both are poisonous to humans. Drinking methanol, at best, causes nausea and vomiting, and may also cause permanent blindness and death. Drinking ethylene glycol can give similar nausea, and can also cause hyperventilation (lack of ability to control fast breathing) and death.[11]

So, if someone is looking for a cheap good time, mistaking ‘alcohol’ in a bottle as being a safe ‘ethanol’ drink could be a very dangerous mistake.

Time For a Break?

After all of this reading, you may be ready for a break - how about a warm, soothing bath? Why not increase your comfort by using a *bath fizzer*? If you’ve never seen a bath fizzer (also known as a “bath bomb”), the name pretty much says it all. When added to a hot bath, a bath fizzer produces a ton of soothing bubbles and some bath oil. The bubble effect is caused by chemistry: The neutralization of a base (baking soda, sodium bicarbonate) with an acid (citric acid, as found in citrus friuts like oranges). The recipe for making the fizzers is given in the ***Activity*** section of this module.

Conclusion

Looking back at the start, we see the name of the module is “What in the World Is Chemistry?”

This module has taken you from Teflon® in clothing stores, to the beauty salon, to the hardware and grocery stores. We see that knowing some chemistry of the world around us not only, explains life's simple things like getting a hair colour, but also the more important things, such as what can poison you and what cannot. At the end of it all, maybe we should change the title of this piece to "What in the World ***Isn't*** Chemistry?"

Understanding Concepts

1. Teflon® is used as a coating on the lenses of glasses and goggles[2,3]. From the information given in the module, explain why Teflon® is used here.

2. A national car parts company[4] sells windshield "Washer Fluid With Teflon®." They claim that the fluid can:
   - Remove dirt and grime for streak-free visibility.
   - Reduce friction for a smoother, cleaner wipe.
   - Eliminate 'chatter' (the loud bumping of a wiper across a clean windshield)
   - Protect against windshield re-freezing

   Think about each point above, and state whether you believe this claim is reasonable or not based on what you know about Teflon®.

3. State the purpose of each compound in permanent hair dyes.
   (a) ammonia
   (b) hydrogen peroxide

4. Why do you think the hair colour envelopes for ammonia and hydrogen peroxide are only mixed when ready to use them, rather than buying them already mixed together in one package?

5. The compound TSP (trisodium phosphate) contains sodium ions and phosphate ions. Some chemistry teachers look at the name of the compound, and start to ask some questions.
   (a) Based on the ions present, what is the correct chemical formula of TSP?
   (b) Is the compound ionic or molecular? Explain in one sentence.
   (c) Why is the common name of TSP - "trisodium phosphate" - an incorrect name if we go by our chemistry naming rules?

6. Why is it wrong to say "They put too much chlorine in the water of the town water supply?"

7. A friend of yours is home alone, and finds a container downstairs with part of the label torn off but the section with "alcohol based formula" still visible on the front. With the parents out of the house, the so-called friend calls you up and asks you to come over for a few swigs of the stuff to "get a buzz on." Keep the idea of legal drinking age out of your answer to him but still tell your friend why his idea is a very dangerous one.

Making Extensions

1. (a) One of the oldest hair dyes for men is Grecian Formula®. This hair dye works by using a solution containing lead ions. Look up the effects of lead in natural systems and list these effects.

   (b) Imagine your uncle is looking to dye his grey hair darker. Would you recommend Grecian Formula®? Why or why not?

2. Look up the terms "oxidation reaction" and "oxidizing agent" to get a deeper understanding of what goes on when hair dyes or bleaches work.

References

1. www.do-it-yourself.de/partner/alpina/alpina_2in1_lack.php
2. www.sola.com.au/apps/news/Teflon%20EasyCare%20Lens%20Coating.htm
3. www.solaoptical.pl/sola_02.htm
4. www.canadiantire.ca
5. www.egyptmonth.com/mag07012000/mag4.htm
6. pubs.acs.org/cen/whatstuff/stuff/7811scit4.html
7. www.folica.com/Grecian_Plus_Gr_d408.html
8. www.homeandgarden.canoe.ca/HGGardening0409/08_fungicide-ap.html
9. www.esemag.com/0596/bleach.html
10. www.emedicine.com/emerg/topic177.htm

Activity

Making Bath Fizzers

What you need:

2 tablespoons	-	citric acid (available at a home-brewing store)
2 tablespoons	-	cornstarch
1/4 cup	-	baking soda
1/4 tsp	-	essential oil or fragrance oil (optional; available at some cosmetics stores)
3-6 drops	-	food colour (various colours)
1-3 tablespoons	-	baby oil, vegetable oil or other non-water containing oil suitable for skin contact

2 bowls
waxed paper

Preparation:

1. Mix all dry ingredients: citric acid, baking soda and cornstarch in a bowl.
2. Mix the fragrance or essential oils and colouring together in a separate bowl (or cup).
3. Slowly mix the liquid mixture into the dry ingredients. Add the baby oil drop by drop, mixing as you go. Check to see how oily the mixture is, and try to form a ball after adding about 1 tablespoon of oil. If the ball breaks apart, then add more oil to the mix. Continue to do so until the smallest amount of oil is added that can keep the bath bomb together in a ball.
4. Place the bath bombs on waxed paper to dry.
5. Allow 24 to 48 hours for the bath fizzer to dry completely. They should be completely dry before storage. Store bath bombs in a tightly sealed container, away from moisture.

   (For larger amounts of bath fizzers, expand the mixture, using the proportions above)

Use:

1. Pour bath to desired warmth.
2. Toss in: 1) a bath fizzer and 2) yourself!
3. Enjoy!

Chemistry:

The chemical reaction employed by the bath fizzer is:

$$3\ NaHCO_3\ (s) + C_3H_5O(COOH)_3\ (s) \rightarrow CO_2\ (g) + H_2O(l) + C_3H_5O(COONa)_3\ (aq)$$

Internet References

www.essentialoil.com/bathbomb.html
www.pvsoap.com/recipe_bath_bomb.htm
www.nexus.chemistry.duq.edu/snes/chemistry/faculty/isenhour/chem121f/Chap04.htm

1-2 Staying Safe on the Job: How to Use Material Safety Data Sheets

Outcomes:

1. Describe the MSD sheet and its use.
2. State the government regulations regarding employers, employees and MSDS.
3. Describe when WHMIS information or MSDS information would be best used.
4. Identify the nine categories on a MSD sheet.
5. Use a MSDS sheet to recognize the hazards associated with consumer products.
6. Use previous examples and examine their MSDS's (Material Safety Data Sheets) to determine:
   - (i) safe storage
   - (ii) safe handling
   - (iii) first aid measures
7. Relate home, workplace and environmental attitudes to the information found on a MSDS.

What is a MSDS, and how is it Different from the WHMIS System?

In Science 2200, we found out that there were several WHMIS symbols that can, at a quick glance, tell us what the hazardous controlled product is inside a container.

> **WHMIS:** Workplace Hazardous MaterialsInformation System
>
> **Controlled Product:** A product, material or substance listed in the Hazardous Products Act (Canada)

The WHMIS symbols are shown for review. Notice that these are just warning symbols. WHMIS symbols do not give us details about how to store, handle or dispose of the substance. WHMIS symbols do not tell us the best first aid response. Now, imagine that you are working in a warehouse that stores and ships a lot of these controlled products. This storage, handling and first aid information would be very important for you to know, especially if there is an accident with the controlled product. This is where a ***Material Safety Data Sheet,*** or MSDS, is used. A MSDS is a sheet that contains information on the possible health effects of a controlled product, and how to work safely with the product.

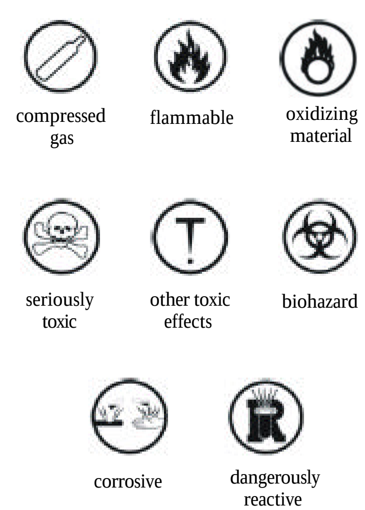


Figure 1. WHMIS symbols and their meanings

A WHMIS symbol is often found on a container of a product giving you a quick idea of its dangers, while a MSDS is a detailed sheet giving a long list of safety information on the substance.

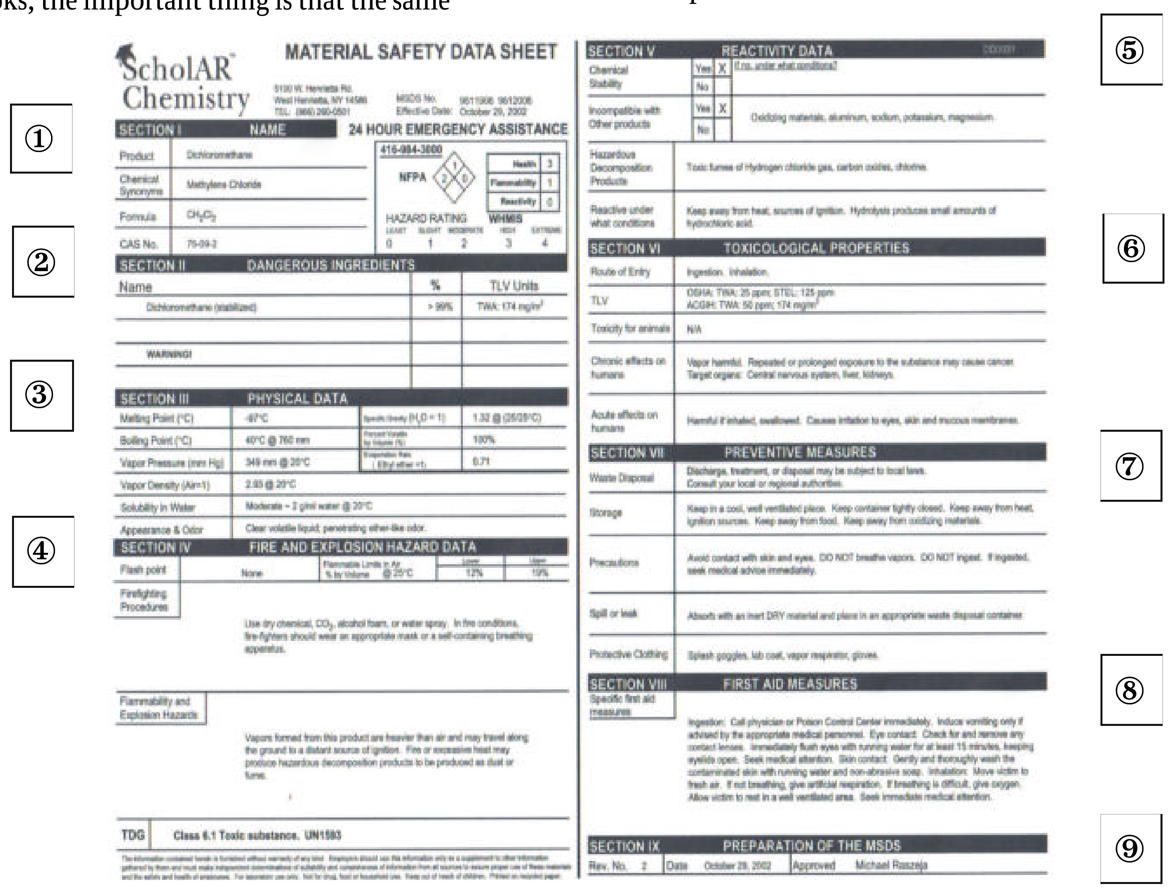
Under Newfoundland and Labrador's Occupational Health and Safety Act, it is law that every employer must make MSDS's available to any employee who may come in contact with a controlled product. These MSDS's are to be updated every three years, in case new safety information is found out about a substance. It is important to realize, before reading any MSDS's, that there will be a lot of very difficult terms on the sheet. It is equally important to know that even the professionals who write these MSDS sheets would need a dictionary on hand to understand every single term. As you look at the sheet below, hopefully you'll see that even though there are a lot of odd or complicated terms, it's not hard to find a lot of understandable, basic safety information on the sheet.

There is no set format or 'look' for a MSDS, so two different MSDS's for the same substance may look completely different. Regardless of how the sheet looks, the important thing is that the same information is found on the MSDS. There are nine different categories on a valid MSDS. The most compact type of MSDS keeps all the information on one sheet, with a black heading, allowing for each category to be found easily.

Figure 2 shows the compact form of MSDS, with all nine headings numbered on the sides.

The headings are:

1. Product Name and Information
2. Dangerous Ingredients
3. Physical Data
4. Fire and Explosion Hazards
5. Reactivity Data
6. Toxicological Data
7. Preventative (Safety) Measures
8. First Aid Measures
9. Preparation of the MSDS


ScholAR Chemistry

MATERIAL SAFETY DATA SHEET

①

SECTION I	NAME	24 HOUR EMERGENCY ASSISTANCE
Product	Dichloromethane	416-984-3000
Chemical Synonyms	Methylene Chloride	NFPA: Health 3, Flammability 1, Reactivity 0
Formula	CH_2Cl_2	HAZARD RATING / WHMIS: 0 Least, 1 Slight, 2 Moderate, 3 High, 4 Extreme
CAS No.	75-09-2	

②

SECTION II	DANGEROUS INGREDIENTS	
Name	%	TLV Units
Dichloromethane (stabilized)	> 99%	TWA: 174 mg/m^3
WARNING!		

③

SECTION III	PHYSICAL DATA		
Melting Point (°C)	-97°C	Specific Gravity (H_2O = 1)	1.32 @ (25/25°C)
Boiling Point (°C)	40°C @ 760 mm	Percent Volatile by Volume (%)	100%
Vapor Pressure (mm Hg)	349 mm @ 20°C	Evaporation Rate (Ethyl ether =1)	0.71
Vapor Density (Air=1)	2.93 @ 20°C		
Solubility in Water	Moderate – 2 g/ml water @ 20°C		
Appearance & Odor	Clear volatile liquid; penetrating ether-like odor.		

④

SECTION IV	FIRE AND EXPLOSION HAZARD DATA			
Flash point	None	Flammable Limits in Air % by Volume @ 25°C	Lower 12%	Upper 19%
Firefighting Procedures	Use dry chemical, CO_2, alcohol foam, or water spray. In fire conditions, fire-fighters should wear an appropriate mask or a self-containing breathing apparatus.			
Flammability and Explosion Hazards	Vapors formed from this product are heavier than air and may travel along the ground to a distant source of ignition. Fire or excessive heat may produce hazardous decomposition products to be produced as dust or fume.			
TDG	Class 6.1 Toxic substance. UN1593			

⑤

SECTION V	REACTIVITY DATA
Chemical Stability	Yes X
Incompatible with Other products	Yes X — Oxidizing materials, aluminum, sodium, potassium, magnesium.
Hazardous Decomposition Products	Toxic fumes of Hydrogen chloride gas, carbon oxides, chlorine.
Reactive under what conditions	Keep away from heat, sources of ignition. Hydrolysis produces small amounts of hydrochloric acid.

⑥

SECTION VI	TOXICOLOGICAL PROPERTIES
Route of Entry	Ingestion. Inhalation.
TLV	OSHA: TWA: 25 ppm; STEL: 125 ppm ACGIH: TWA: 50 ppm; 174 mg/m^3
Toxicity for animals	N/A
Chronic effects on humans	Vapor harmful. Repeated or prolonged exposure to the substance may cause cancer. Target organs: Central nervous system, liver, kidneys.
Acute effects on humans	Harmful if inhaled, swallowed. Causes irritation to eyes, skin and mucous membranes.

⑦

SECTION VII	PREVENTIVE MEASURES
Waste Disposal	Discharge, treatment, or disposal may be subject to local laws. Consult your local or regional authorities.
Storage	Keep in a cool, well ventilated place. Keep container tightly closed. Keep away from heat, ignition sources. Keep away from food. Keep away from oxidizing materials.
Precautions	Avoid contact with skin and eyes. DO NOT breathe vapors. DO NOT ingest. If ingested, seek medical advice immediately.
Spill or leak	Absorb with an inert DRY material and place in an appropriate waste disposal container.
Protective Clothing	Splash goggles, lab coat, vapor respirator, gloves.

⑧

SECTION VIII	FIRST AID MEASURES
Specific first aid measures	Ingestion: Call physician or Poison Control Center immediately. Induce vomiting only if advised by the appropriate medical personnel. Eye contact: Check for and remove any contact lenses. Immediately flush eyes with running water for at least 15 minutes, keeping eyelids open. Seek medical attention. Skin contact: Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Inhalation: Move victim to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Allow victim to rest in a well ventilated area. Seek immediate medical attention.

⑨

SECTION IX	PREPARATION OF THE MSDS	
Rev. No. 2	Date October 29, 2002	Approved Michael Raszeja

Figure 2. A MSDS sheet for a chemical called dichloromethane. Note the nine different headings.

While the meanings of some of the headings such as "Dangerous Ingredients" are common sense, other headings like "Reactivity Data" need more explaining. We will now go through each heading, and highlight the common useful information found under each heading.

MSDS Headings

1. Product Name and Information

This is where the name of the controlled substance is found. Some substances have old fashioned names and these would be found here. The maker and supplier of the substance are also given here, along with very important emergency telephone numbers.

2. Dangerous Ingredients

Any nasty ingredients are listed here. In the case of pure chemicals, the chemical name is just repeated from Section 1. In the case of mixtures, where the actual chemical ingredients are less obvious, this is where the true chemical names of the ingredients are found. For example, the dichloromethane MSDS shown in Figure 2 would be provided with household cleaners or paint thinners which contain dichloromethane.

3. Physical Data

This is where boiling and melting points, water solubility, appearance and odour are found. When we talk about the boiling point of a liquid, we often think that the boiling point temperature will be high, such as the boiling point of water (100°C). Yet, many liquids have much lower boiling points. Can you find the boiling point of dichloromethane in Figure 2?

Solubility: The ability of a substance to dissolve in a solvent such as water

4. Fire and Explosion Hazards

This is one of the more "common sense" headings. This section is very useful in stating which type of fire extinguishers and equipment would be best for fighting a fire that involves this substance. Dangerous substances that may form as the product is on fire are also listed here. Note that you may decide not to even try to fight a fire based upon what you read as dangerous fire/smoke products of the chemical.

5. Reactivity Data

This section states a lot of information about how the chemical could decompose on its own or dangerously react with another substance.

If the controlled product is listed as "not stable", then that means it has to be stored and handled very carefully on its own. "Hazardous decomposition products" would then list the nasty substances which form if the substance decomposes.

If the controlled product is "incompatible with other products", then this lists the things to *keep away* from the chemical.

6. Toxicological Data

Though the heading is a long one, this section simply lists how the controlled product is poisonous.

"Route of entry" indicates how a substance may get into the body. Some chemicals enter easily through simple skin while others must be inhaled or eaten (i.e. "ingested") to enter.

"TLV" means "Threshold Limit Value." The TLV is an estimate of how much substance can enter your body before ill effects are expected. Many chemicals have their TLVs listed in a unit called "ppm" or "parts per million". The "ppm" unit is a very small amount. So, if a substance has low ppm values (less than 1000ppm for the TLV), then all precautions should be taken in dealing with the material to keep it from entering the body.

"Chronic Effects" and "Acute Effects" are also listed. Simply put, "chronic" means "long term" effects while "acute" means "short term" effects. Recall, while short term harm may ruin your plans for the evening, long term harm will still harm you in the long run!

7. Preventative (Safety) Measures

This is probably the most useful section for a worker who is working with a controlled product. Before using the controlled product, a worker should match the name on the product's label with its MSDS, and read this section. This way, before even touching the product, the worker will know exactly what safety precautions to take. The headings here include waste disposal, clean up of spills, storage and what protective clothing to wear.

8. First Aid Measures

Sometimes, no matter how careful we are and how well prepared we are to handle a controlled product safely, accidents still do happen. This section of the MSDS is the source of first aid information. Given that we cannot predict when accidents are going to happen, it is just as important to read the first aid measures before using the product as it is to read the safety precautions in the section above.

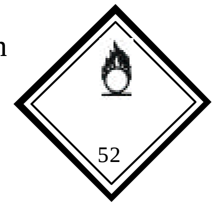
9. Preparation of the MSDS

The information on the MSDS has to be accurate and up to date, so the name of the official person who approved the information is listed. On some MSDS's additional special precautions are listed here.

The Final Word

MSDS's come in different forms, often with terms and language which seem impossible to understand. The important thing to remember is that, with the basic knowledge that this module gives you about MSDS's, you can now sift through the information to come up with emergency phone numbers, fire fighting measures, basic safety ideas, and first aid. So don't get turned off by the 'look' or the language of a MSDS; use the MSDS. It just might save your life on the job someday.

Understanding Concepts



1. The symbol shown was found on the back of a truck, that was overturned on the highway just outside of town. What is in the back of the truck?
2. For each situation given, state whether a WHMIS symbol or a MSDS should be used:
   (a) on a bottle, to give a warning at a glance
   (b) to give first aid information
   (c) on a box for shipping
   (d) on a container for storage
   (e) to decide what materials should be stored next to the controlled product

   Use the MSDS for dichloromethane (Figure 2) to answer questions 3 to 9.

3. (a) What is the boiling point of dichloromethane?
   (b) If you are working in a warehouse which stores dichloromethane, what would you think if your boss asked you to stack cartons of dichloromethane next to the warehouse heaters?
4. Look at the Reactivity Data on dichloromethane's MSDS. What types of common containers would you:
   (a) NOT use to store dichloromethane
   (b) use to store dichloromethane.
5. According to the information in Sections 4 and 5, state TWO reasons why a dichloromethane fire would be more dangerous than a wood fire.
6. Read the chronic and acute effects of dichloromethane on humans. If you were using a paint thinner that has dichloromethane in it, what possible problems could improper use of this thinner cause:
   (a) in the short term, and
   (b) in the long term?

7. A small child drinks a sip of window cleaner containing dichloromethane.
   (a) In point form, list what should be done in response to the accident.
   (b) Many parents of young children decide to use bubble bath as a window cleaner. What do you think about this idea?

8. After cleaning up some paint brushes safely, a painter decides to dump the thinner (containing dichloromethane) in the patch of trees behind his house. Comment on this, based upon what you know from the MSDS of dichloromethane.

9. Is the MSDS for dichloromethane in Figure 2 outdated? How do you know?

10. Your boss comes up to you and says: "Don't worry about wearing gloves with that stuff - the MSDS says it has no acute effects, just a few chronic effects." Do you think you should grab a set of gloves anyway? Why? Why not?

Making Extensions

1. The format/'look' of the dichloromethane MSDS in Figure 2 is just one of the accepted formats. Search the internet, school lab or learning resource centre for Material Safety Data Sheets with a different format/'look'.

2. Many communities around Newfoundland and Labrador have pick-up dates for hazardous household materials. These dates are usually held in the summer. Even though it is not now summer, call your town office to find out if there is a hazardous materials pick-up day for your area, when and where it is usually held, and what types of materials they take.

3. Research the careers of a hazardous materials technician or materials safety officer. You may wish to contact community colleges or private trade schools to find out what kinds of training programs are offered in the province.

References:

www.ccohs.ca/oshanswers/legisl/msdss.html

www.ccinfoweb.ccohs.ca/help/msds/msdsCDNGUIDE.html

www.ccohs.ca/products/msds/msdsservice.html

www.ccohs.ca/oshanswers/

www.muextension.missouri.edu/xplor/agguides/agengin/g01913.htm

www.hc-sc.gc.ca/hecs-sesc/whmis/index.htm

www.em.robins.af.mil/pollution/epa.htm

www.whscc.nf.ca/

1-3 From Alchemy to Chemistry

Outcomes:

1. Describe alchemy and compare the alchemy of early civilizations and the Middle Ages to the practice of chemistry today. (NLS-1)
2. Use a classification system to describe how Mendeleev developed the periodic table of elements as a means of organizing elements, some of which were not yet discovered. (210-1)
3. Explain the roles of evidence, theories, and paradigms in the development of Mendeleev's periodic table of elements. (114-2)
4. Identify new questions and problems that arise from what was learned by looking at some unexpected discoveries in the history of chemistry. (210-16)
5. Identify vertical columns as groups or families which exhibit similar properties.
6. Identify metals, nonmetals, and non-reactive gases (Noble gases).
7. Provide examples of how chemistry is an integral part of our lives and our community by looking at some interesting discoveries in the history of chemistry. (117-5)

Alchemy: Chemistry's Beginning

"Chemistry" as we know it today first came from "alchemy". In ancient Egypt, the word "***khem***" referred to the fertile area around the Nile River - where Egyptians developed a lot of basic chemical knowledge as they preserved mummies, blended metals into alloys, and dyed fabrics. At the same time, India, Tibet and China in the Far East developed their own version of primitive alchemy.

Alloy: A mixture of metals, such as brass

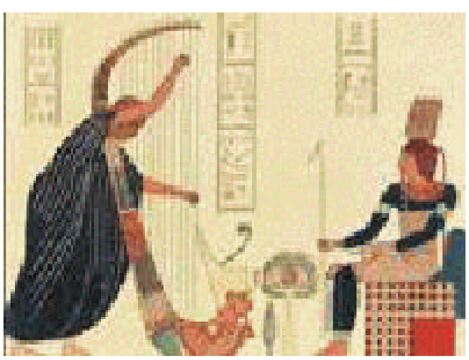


Figure 1. Egyptian alchemists heat a chemical reaction.

After Alexander the Great conquered Egypt for Greece in 332 BC, followed by the Arabs invading Egypt in the 7th century, alchemy spread both East and West. The Arabs came up with the idea of ***The Philosopher's Stone*** - a substance which could magically turn cheap lead metal into precious gold and even prolong life.

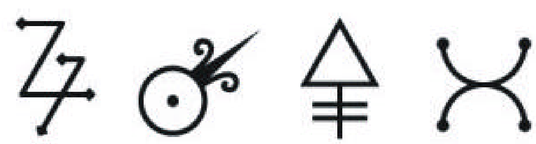


Figure 2. Alchemist's Symbols. From left to right, lead, gold, phosphorus and tin.

The Arabs then took alchemy to Spain in the 8th century. From this point, the lure of becoming instantly rich by finding The Philosopher's Stone spread the idea of alchemy through the rest of Europe.

From this time to the 16th century, hundreds or even thousands of alchemists over the years tried, yet failed in finding The Philosopher's Stone. After this time, alchemy faded away into history.

The difference between what was called “alchemy” in the 16th century and the “chemistry” that followed after is that “chemistry” is studied with more than just the trial and error “mix this with mix that” attitude that was done by alchemists. Chemists look for how substances behave, and then will usually combine one substance with another because they know they should react. Chemistry then, is scientific. It is done with some reason and order. Alchemy was more black magic and out-of-this world dreams of stumbling by luck on a substance that could make you rich and live forever (though that wouldn’t be bad, either)!

The main tool that allows a chemist to see trends between different elements is the Periodic Table, develped by a Russian named Dimitri Mendeleev in 1870. This module will show you how important he was in making up this table. Now this is not to say that today’s chemists never get lucky with their experiments. This module will also describe some of chemistry’s more lucky discoveries for several substances that we commonly use today.

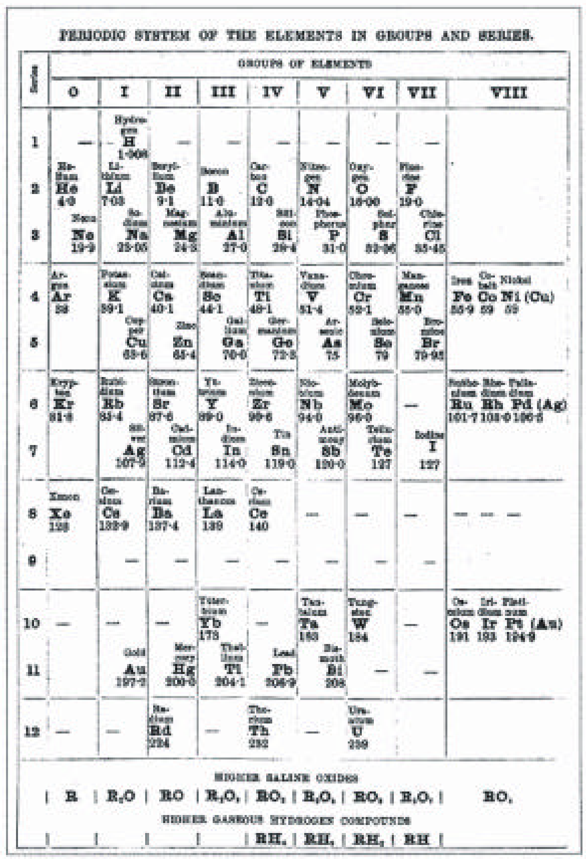
Mendeleev’s Periodic Table

Dimitri Mendeleev was born in Siberia, Russia in 1834. When Mendeleev became a professor of general chemistry, he was unable to find good textbooks and thus began writing his own. This gives you an idea of the type of person Mendeleev was.

Figure 3. Mendeleev.

When Mendeleev was writing his book between 1868 and 1870, chemists had discovered around 60 elements. Chemists also knew how to measure the atomic weight of each element, so he also had the weight of each element compared to the weight of hydrogen. So, Mendeleev started to write down the known elements and their weights on separate cards. He then placed the cards in the order of the atomic weights.

As he looked at the cards in order, he realized that there were elements that behaved in similar ways. So he kept the cards in order, but instead of just placing the cards in a straight line from lowest weight to highest, he started to put cards of heavier elements below cards of lighter elements that acted in similar ways.



PERIODIC SYSTEM OF THE ELEMENTS IN GROUPS AND SERIES.

Series	0	I	II	III	IV	V	VI	VII	VIII
1	—	Hydrogen H 1·008	—	—	—	—	—	—	
2	Helium He 4·0	Lithium Li 7·03	Beryllium Be 9·1	Boron B 11·0	Carbon C 12·0	Nitrogen N 14·04	Oxygen O 16·00	Fluorine F 19·0	
3	Neon Ne 19·9	Sodium Na 23·05	Magnesium Mg 24·3	Aluminium Al 27·0	Silicon Si 28·4	Phosphorus P 31·0	Sulphur S 32·06	Chlorine Cl 35·45	
4	Argon Ar 38	Potassium K 39·1	Calcium Ca 40·1	Scandium Sc 44·1	Titanium Ti 48·1	Vanadium V 51·4	Chromium Cr 52·1	Manganese Mn 55·0	Iron Cobalt Nickel Fe Co Ni (Cu) 55·9 59 59
5		Copper Cu 63·6	Zinc Zn 65·4	Gallium Ga 70·0	Germanium Ge 72·3	Arsenic As 75	Selenium Se 79	Bromine Br 79·95	
6	Krypton Kr 81·8	Rubidium Rb 85·4	Strontium Sr 87·6	Yttrium Y 89·0	Zirconium Zr 90·6	Niobium Nb 94·0	Molybdenum Mo 96·0	—	Ruthenium Rhodium Palladium Ru Rh Pd (Ag) 101·7 103·0 106·5
7		Silver Ag 107·9	Cadmium Cd 112·4	Indium In 114·0	Tin Sn 119·0	Antimony Sb 120·0	Tellurium Te 127	Iodine I 127	
8	Xenon Xe 128	Cesium Cs 132·9	Barium Ba 137·4	Lanthanum La 139	Cerium Ce 140	—	—	—	— — —
9		—	—	—	—	—	—	—	
10	—	—	—	Ytterbium Yb 173	—	Tantalum Ta 183	Tungsten W 184	—	Osmium Iridium Platinum Os Ir Pt (Au) 191 193 194·9
11		Gold Au 197·2	Mercury Hg 200·0	Thallium Tl 204·1	Lead Pb 206·9	Bismuth Bi 208	—	—	
12	—	—	Radium Rd 224	—	Thorium Th 232	—	Uranium U 239		
HIGHER SALINE OXIDES	R	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4
HIGHER GASEOUS HYDROGEN COMPOUNDS					RH_4	RH_3	RH_2	RH	

Figure 4. Mendeleev’s First Periodic Table.

This was Mendeleev’s first Periodic Table. Going ***across*** a row in the table, the elements got heavier; going ***down*** a column, the group of related elements acted in similar ways.

We now call a ***row <u>across</u> the periodic table a <u>period</u>; we call a column going <u>down</u> the periodic table a "<u>family</u>" or "<u>group</u>."***

Note that there are "holes" in Mendeleev's periodic table. In order for his table to work, he had to skip spots in the table to have elements with similar behaviour line up with their family members above and below. Mendeleev was bold enough to suggest that new elements not yet discovered would be found to fill the blank places. He even went so far as to predict the properties of the missing elements, based upon the elements in the family above or below the blank spots!

Today, over 110 elements are known, and Mendeleev's original table has hardly changed, other than to fill in the elements that he predicted would be discovered!

Chemistry Luck

Mendeleev's work on figuring out the Periodic Table is an excellent example of how chemistry can follow a system, a pattern, and be a very predictable science. Yet there still is an "alchemy" side to chemistry, especially when something very unexpected happens. As you will see, many of these lucky chemistry events have worked their ways into our everyday lives.

1. Silly Putty

At one point in time you may have owned your own 'egg' of Silly Putty - that soft, rubber-like goop that can be pressed into shape like modeling clay or even copy cartoons from a newspaper. Yet, it was a fluke that Silly Putty was even invented.

Rubber was scarce during World War II, so a General Electric engineer tried to come up with a similar substance by combining two main ingredients: boric acid and silicone oil. The result? A peculiar glob of goo that was useless as a rubber substitute.

But, as it turned out, there was still a future for this bouncy stuff. A man named Peter Hodgson discovered the nutty putty at a party in 1949. He thought it might make a cool toy. So Hodgson borrowed $147, bought the rights from General Electric, and produced the first batch of Silly Putty!

Since 1950, more than 300 million Silly Putty eggs have been sold - which is enough to create a giant wad the size of the Goodyear Blimp. The pinkish compound is now sold in 16 different colours including metallic gold and glow-in-the-dark.[6]

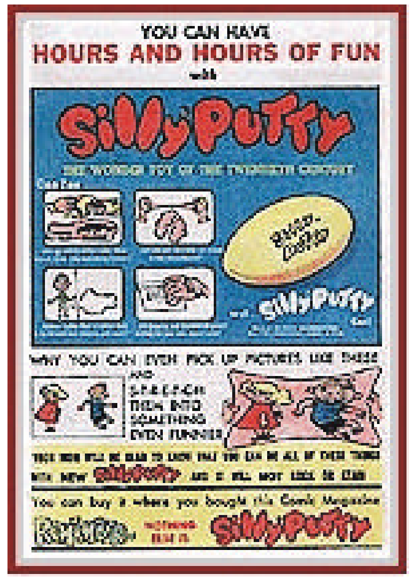


Figure 4. A Silly Putty ad from the 1970s.

2. Aspartame

Aspartame is likely the world's most common substitute for suger. It is the substance found in Nutrasweet®, Sweet-n-Low®, or Equal®, and almost every diet soft drink on the market today.

It was discovered in December 1965 at G.D. Searle. A chemist by the name of Jim Schlatter was working in a lab that was searching for new treatments for stomach ulcers. In order to test the treatment, Schlatter needed to make a protein that is normally found in the stomach. In one of the steps along the way, Schlatter made a white crystal product which he accidentally spilled on his hand.

Later that day, he licked his finger to pick up a piece of paper; he noticed right away that his finger tasted particularly sweet. At first, he thought it was from the doughnut he had eaten on his coffee break, but after remembering he had washed his hands, he went on and tasted the aspartame.[7] As the story goes, he next tried some in his coffee, and the rest is history.

3. Teflon®

If you have used a set of downhill or cross country skis, or if you would rather cook your bacon and eggs in a non-stick frying pan than an old hard to clean cast iron frying pan, chances are you have used Teflon®. According to the Guinness Book of World Records, Teflon® is the slipperiest substance known to man. Yet it was a fluke that it was discovered.

Figure 6. Thanks to Teflon, these won't need to be scrubbed...

Teflon was discovered in 1938 by Dr. Roy Plunkett and his assistant, Jack Rebok, in the laboratories of chemical manufacturer DuPont. They were studying the behaviour of a newly prepared fluorine-carbon gas to figure out if it would be any good to use in refrigerators as a coolant gas.

After making the gas one day, it was stored overnight in high-pressure cylinders. When the two came in the next day, they couldn't get any gas out of what should have been a full cylinder.

Initially, they thought the cylinder was defective and that the gas had slowly leaked out, but then they realized the cylinder weighed a lot more than an empty one.

Amazed by this, they decided to cut the cylinder in half (do NOT try this at home!) and, to their surprise, they found a slippery white powder inside.[8]

Thus Teflon was discovered and, in the more than 65 years that has passed, the compound has made millions of dollars for the DuPont chemical company.

4. Dynamite

One of the most amazing chance discoveries in science was the discovery of dynamite by Swedish scientist Alfred Nobel in 1873. Then, in a roundabout way, it also led to creation of today's Nobel Prizes.

Figure 7. Alfred Nobel.

It happened when Nobel was trying to control the super-powerful explosive nitroglycerin. Many accidents back then involved the very unstable nitroglycerin which killed hundreds of people. The substance, also known at the time as blasting oil, even killed Alfred's brother, Emil.

In the lab, Nobel combined many substances with nitroglycerin. He tried sawdust, cement powder, ground charcoal and even brick dust. But none of these made the explosive any easier to handle.

One day, Nobel noticed nitroglycerin was leaking from its storage casks and being soaked up by the natural powder "diatomaceous earth", which was used to pack and protect the containers. When he examined the leak, Nobel found the diatomaceous earth absorbed three times its own weight in blasting oil.

More importantly, the dry nitroglycerin-diatomaceous earth mixture could be hit with a hammer and even set afire without exploding. Only a blasting cap would set off the new explosive, which became known as dynamite.

Nobel became extremely rich from this discovery. However, he was troubled by the death and destruction caused by some who used dynamite for terrorism or in war. So, to help offset some of the craziness and destruction caused by what he saw as misuse of his discovery of dynamite, Nobel used his great wealth to set up yearly cash awards in many areas, such as Chemistry and Peace - the Nobel Prizes were born.[9]

Conclusion

Chemistry has come a long way from its days of alchemy... or has it? While chemists today use tools like the periodic table to try to predict the results of their reactions, sometimes (as we see from the weird discoveries above) they get a lot more than they bargained for!

Understanding Concepts

1. (a) Define the following as it relates to the periodic table:

   (i) family

   (ii) group.

   (b) List three elements that are in Group IIA.

   (c) List three elements that are in period 3.

2. Sodium reacts with water by producing a gas and catching on fire in less than a minute. Potassium reacts with water by producing a gas and catching on fire in a few seconds.

   (a) What do you think would happen to a piece of cesium metal placed in water?

   (b) What idea from Mendeleev's periodic table did you use in your answer to part (a)?

3. Make a statement on whether you think it was good lab practice when Schlatter, who discovered aspartame, "licked his finger to pick up a piece of paper."

4. Teflon is commonly used in the material of men's shirts. Why would Teflon be used here?

Making Extensions

1. Look up "the vulcanization of rubber" to find out what this means, and how the rubber in car tires is treated before being used in making tires.

2. Teflon is used in a huge number of products. Use the internet to find five different uses for Teflon.

3. Use the internet to find out what areas Nobel Prizes are given in, the cash amount of the awards, and the most recent winners.

Activity

Silly Putty Recipes! Click on...

1. bulkputty.org/creations/SillyPutty.pdf (***Teacher assistance will be needed.)***
2. www.ericjorgensen.com/html/slime.htm

If you have problems, the recipes for Silly Putty and Slime are given below:

SILLY PUTTY

Silly Putty can be successfully approximated with Elmer's Glue instead of silicone oil. The recipe below makes a small, palm-sized ball:

1 fluid ounce of 50% Elmer's Glue solution in water;

5 mL of 4% sodium tetraborate (Borax - available at a drug store) solution in water and

a few drops of food colouring.

Mix the food coloring with the Elmer's Glue solution. Add the 5mL Borax solution and stir for 2 minutes. Roll around the lump in your hands for two minutes, after which time it will cease to be sticky. Store the putty in a clean, covered container.

SLIME

Many toy stores sell one form or another of coloured Slime. Usually they come in small tubs, are slightly unpleasant-smelling, and are cold and clammy to the touch (apparently because of a heat-absorbing reaction). The recipe below is the exact recipe for commercial Slime, and makes a small, palm-sized amount:

1 fluid ounce of 5% polyvinyl alcohol (acid-free art glue) solution in water;

several mL of 4% sodium tetraborate (Borax) solution in water;

a few drops of food colouring.

Mix the food colouring with the polyvinyl alcohol solution. Add one millilitre of the Borax solution and stir like crazy for 2 minutes. Adding more Borax solution will yield thicker slime if desired; nice thick slime can be had with approximately 4-5 mL of Borax solution per fluid ounce of polyvinyl alcohol solution. Store the slime in a clean, covered container.

References

1. www.chemsoc.org/exemplarchem/entries/2002/crabb/flash.html
2. www.alchemylab.com/history_of_alchemy.htm#Egyptian%20Alchemy
3. www.alchemylab.com/contents_solar.htm
4. hemistry.about.com/od/alchemicalsymbols/a/alchemyindex.htm
5. www.aip.org/history/curie/periodic.htm
6. www.gp4k.com/frontpage/Article.asp?ID=307
7. www.wfu.edu/users/moshas1/fysproject.htm
8. neon.otago.ac.nz/chemistry/magazine/chmat24.htm
9. www.northernexpress.com/editorial/features.asp?id=858

1-4 From Light Bulbs to Fireworks

Outcomes:

1. Use models (the Bohr model of the atom) in describing the structure and components of atoms and ions. (307-14)
2. Define photon.
3. Define the terms ground state and excited state for atoms.
4. Describe a photon of light as being produced when an excited electron relaxes back to a lower energy level.
5. Provide examples of how science and technology are an integral part of our lives and our community, using the examples of light bulbs and fireworks. (117-5)
6. Identify new questions and problems that arise from what was learned. (210-16)

Introduction

Where would we be in this world if we could not produce light when we need it? Easy: in the dark! Many of the things we use on a daily basis we take for granted, especially if they seem to have been around forever. For example, we don't think twice when we reach for a switch to turn on a light. Yet, if we stop for a second to think: How is the light bulb made? How does the light bulb work? What causes a light bulb to blow? This module will answer each of these questions, and show there's a lot of basic chemistry at work every time a light bulb glows. We will also look at the chemistry behind a fireworks show and see just how all of those wild colours are made. But first, we need to get an idea of how atoms can be made to produce light.

Bohr Atoms and Light Photons

To understand how light can come from atoms, we first have to make sure we can draw Bohr diagrams. As an example, we can look at the Bohr diagram for calcium, as shown in Figure 1.

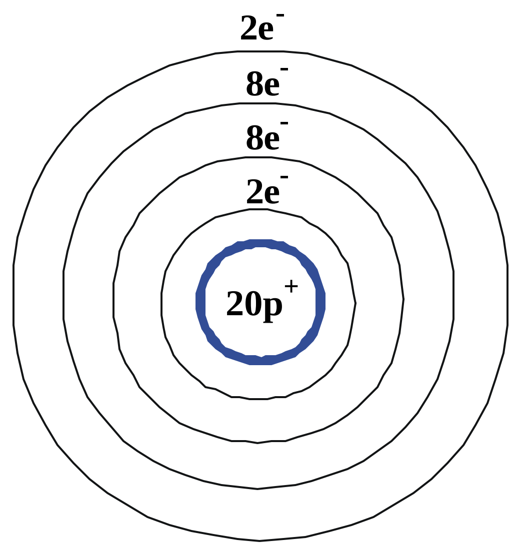


Figure 1. The Bohr diagram for calcium.

The diagram shows that calcium has twenty protons in a nucleus ("$20p^+$") with twenty electrons ("e^-") outside the nucleus. Remember that the electrons aren't just in the one single 'orbit' around the nucleus; they are split into several orbits. With the first orbit taking a maximum of two electrons and the second and third level taking a maximum of eight electrons each, we get the twenty electrons spread out over four orbits: $2e^-$ in the first, $8e^-$ in the second, $8e^-$ in the third, and $2e^-$ in the fourth.

This Bohr diagram is the correct ***ground state*** diagram for calcium. The term "ground state" is like talking about the "ground level" in a high-rise building. Just as the ground level is the lowest level of the building; the ground state is the lowest energy level for an atom. If you walk into the ground level of a building, you can walk back out without much effort... pretty relaxed movement. For an atom, the ground state is also the 'most relaxed' level, the way you'd usually draw the Bohr atom as you were shown in class.

In a building, it takes energy to walk the stairs to the higher levels. For an atom, energy also has to be put in to get to higher energy levels. This "energy in" can be in different forms, such as heat energy or electrical energy. For a building, you put in the energy to walk the stairs, and in the end you get yourself on a higher floor - a higher level - in the building. For an atom, if electrical energy, say, is put in, you can put an electron from a low orbit - a low level - into a higher orbit - a higher level. An atom with electrons in 'higher orbits' than the ground state is called an ***excited state*** atom.

For example, the ground state diagram for calcium is drawn in Figure 1. If this ground state calcium atom in Figure 1 is given a jolt of electrical energy or a blast of heat, this "energy in" may be enough energy to ***excite an electron*** from a low level to a higher level. The electron can come from any of the 'regular' ground state levels. What's more is that the 'excited electron' can jump to a level that we had not drawn in the 'regular' ground state atom before, a level we didn't draw because we didn't need it - we had no electrons to put in it. Check it out: Figure 2 shows a calcium atom which has been zapped with electrical energy, enough to excite an electron from the third level out to a ***fifth level***. Remember: We didn't have a fifth level before (Figure 1), but *we didn't need it before* in the ground state atom.

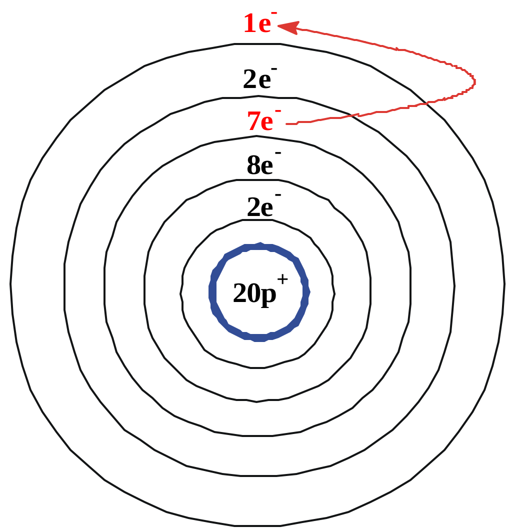


Figure 2. An ***excited state*** Bohr diagram for calcium. The 'regular' ground state calcium atom (shown back in Figure 1) has been zapped with enough energy to push an electron from the third level out to a previously unused fifth level out (as shown by the arrow).

Now, here's where we can explain how an atom can produce light. Think: if we ***put energy in*** to our bodies in the form of food, we can ***later use this energy*** to do exercises such as running or skating. An atom is the same. If we take a 'regular' ground state atom and ***we put in energy*** (zap it with heat or electricity), we are really storing energy in the atom by exciting the electron to a higher level. This excited atom will ***later relax back to its 'regular' ground state orbit, and the energy is released as a packet of light.*** This 'packet of light energy' is also called a ***photon.*** This whole process is shown in Figure 3. For the calcium atom shown back in Figure 2, the electron that was excited in the fifth level will eventually fall back to its proper place - the third level, and the energy it loses in the trip back down is released as a light photon.

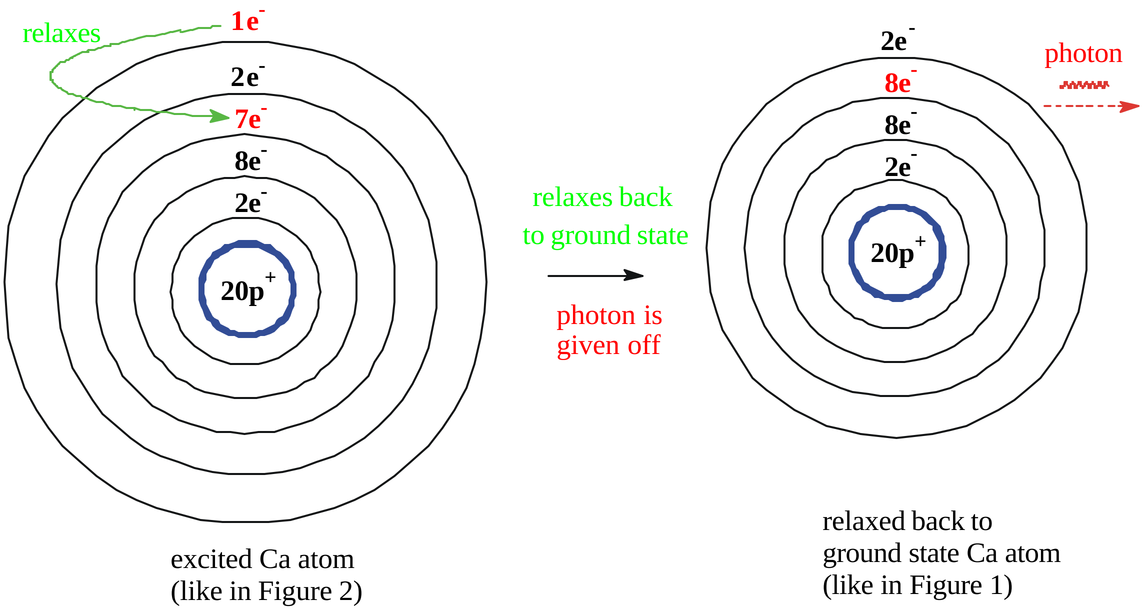


Figure 3. A photon is produced when an excited atom (left side) relaxes back to the round state (right side).

The Light Bulb - How it Works

If we can understand the above on how an atom can produce light, then we can explain how light bulbs or fireworks work.

The light bulb was invented by Thomas Edison in 1879, using a filament which was a cotton thread coated with carbon. This filament burned out after only fifteen hours.[1] Can you imagine having to change each light bulb in your house after only fifteen hours of use?

> **Filament:** The thin wire inside a light bulb, which glos when heated to produce the light

Nowadays, the filament used in light bulbs is tungsten (periodic table symbol "W", from its German name "Wolfram".) Edison thought of using tungsten, but the tools available at the time kept him from doing so. In fact, Edison is quoted as saying: "I tested no fewer than 6,000 vegetable growths and ransacked the world for the most suitable filament material."[1]

The tungsten filaments such as the ones in light bulbs today were developed in 1910 by chemists at the General Electric Company in the US. A cutaway drawing[2] of a light bulb (Figure 4) shows the different parts and helps to explain the chemistry and physics of how a light bulb works.

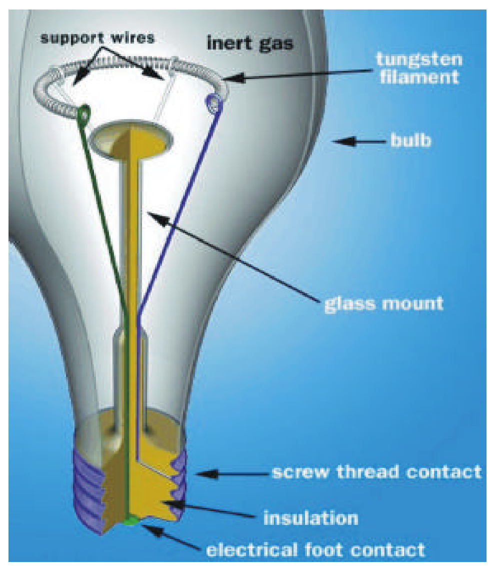


Figure 4. Parts of a light bulb.[2]

Light bulbs have a somewhat simple working structure. At the metal base, they have two metal contacts (the "screw thread" and the base's "foot"), which are screwed into the bulb's socket. The metal contacts are attached to two stiff wires which run inside the bulb. These wires are attached to the thin tungsten filament. The filament sits in the middle of the bulb, held up by a glass mount. The wires and the filament are housed in the outer glass bulb.[2] The bulb has the air removed, and in its place a **noble gas**, such as argon (symbol "Ar"), is pumped in and the bulb is sealed.

When you flick a light switch, an electric current flows through the two contacts, the wires, and most importantly, the filament. The filament heats to about 2,200°C in today's light bulbs. At this high temperature, the filament still does not burn. The light is actually produced by electrons in the tungsten filament being "excited" (by the electricity) to high energy levels in the atom, then relaxing back to their 'proper' ground state levels - just in the same way as described in the first part of this module.

It is important to note that the light from a regular light bulb is not made from burning the filament. Remember that burning is a chemical reaction that needs oxygen to work. Light bulbs are filled with noble gases like argon - gases that do not react. With argon taking the place of oxygen in a light bulb, the bulb works properly. If a crack forms in a light bulb and some air (with oxygen) goes in, the light bulb burns its filament and blows.

How's that for 'chemistry around the home'? Next time you go to flick a light switch, take a second to think about the amount of chemistry at work between the second your finger touches the switch and the split second later that the light bulb comes on.

Fireworks - How They Work

Just about anyone loves a good fireworks show. The loud bangs and pops, the different shapes of the blasts, some of them creeping up and giving a huge bright starburst, or sometimes a bunch of flickering bright lights. Fireworks come in a variety of shapes, sizes, sounds, and, of course, colours. But how do they get the different colours? Read on.

The early part of this module explained how a photon of light can come from an atom's electron energy levels. Now think: if different atoms have different numbers of electrons, then changing the atom will change the number of electrons and the energy levels. So - if the photons of light come from these electrons

Figure 5. A typical fireworks show.[3]

in excited energy levels, then ***changing the elements in a blast of fireworks will change the colour of the fireworks.***

The table[4] below lists the different compounds used in fireworks and the colour of each compound when 'lit up.'

Colour	***Compound***
bright red	strontium carbonate
orange	calcium chloride calcium sulfate
golden yellow	iron filings iron powder
bright yellow	sodium nitrate
green	barium chloride
blue	copper(l) chloride
bright white	magnesium or aluminum powder

Note that it is the metal that gives the colour of the compound, not the nonmetal part of the compound. It's as simple as that.

Also many of these colours are primary colours. If you want a colour such as purple in a fireworks blast, the right primary colours (compounds from the table) need to be added when the fireworks blast is packed.

The Last Word...

Science often gets a bad name for being 'out of this world' or 'too complicated to explain anything useful.' Notice that, if you can get the ideas of ground state atoms, excited state atoms, and photons, you can explain how not only light bulbs work, but even how fireworks work. You should also know that this is not simple science - it wasn't so long ago that Nobel prizes were being won for knowing science like this. So, flick that switch and turn on the lights, or go to those Canada Day fireworks and watch the show - feel confident in the so-called 'out of this world' chemistry that you know.

Understanding Concepts

1. Define:
   (a) ground state atom
   (b) excited state atom
   (c) photon
2. For the element magnesium, Mg:
   (a) draw the Bohr diagram for the ground state of magnesium
   (b) draw the Bohr diagram for the excited state of magnesium, where an electron from the third level has jumped to the previously unused fifth level.
   (c) The bright light (photons) from burning magnesium occurs when an excited magnesium atom (like in your picture in (b)) has its electron in the fifth level relax back down to the ground state level (such as in your picture in (a)). Re-draw your diagrams from (a) and (b) to show how these bright light photons are produced by relaxing magnesium atoms. (You may want to use Figure 3 in the module as a guide.)
3. For a regular light bulb, explain how the electrons in the tungsten filament produce the light, not actual burning of the filament.
4. Why can there be no air inside a light bulb?
5. Most light bulbs today, when they are made, are pumped full of argon gas.
   (a) State why light bulbs are pumped full of argon.
   (b) State two other gases that would do the same job as argon in a light bulb and state why they would work.
6. The Hockey Hall of Fame is putting off a fireworks show at the end of the 2084 Stanley Cup Playoffs between the Toronto Maple Leafs and the Montreal Canadiens. The fireworks company is told to blast off fireworks in the team logos of the Leafs and the Canadiens.

   What compound could the fireworks company use to get the:
   (a) Leafs logo?
   (b) Canadiens logo?
7. A fireworks company wants to make purple fireworks for a job, but only has the compounds listed in the table in the module you just read. What compounds could the company mix to get a purple firework blast?

Making Extensions

1. Do research to find out why argon is used in most light bulbs instead of other noble gases.
2. Do research on not only the colours in fireworks, but also how the fireworks are shot up into the sky, and how they give different shapes of blasts.

Activities

1. Fireworks Colours - Teacher Demonstration

For the substances listed in the Table in the module, take a small (pea sized) amount of each substance on the end of a lab spatula and burn it in a Bunsen burner or blowtorch flame. Enjoy!

2. Fireworks Colours - Student Lab Version

Go to the internet link, Reference 4.

3. Make Some Coloured Fire Logs!

Go to the internet link, Reference 5.

3. Make Some Sparklers!

This is tough to get right. Go to the ***Journal of Chemical Education*** citation:

Keeney, Allen; Walters, Christina; Cornelius, Richard D. Making Sparklers: An Introductory Laboratory Experiment *J. Chem. Educ.* **1995** *72* 652.

This article's abstract is found on the internet; see Reference 6.

References

1. www.ideafinder.com/history/inventions/story074.htm
2. science.howstuffworks.com/light-bulb2.htm
3. www.tripsource.com/stories/Andy/Andy/Trip9/Aust2/fireworks%201.jpg
4. nasaexplores.nasa.gov/show_912_student_st.php?id=030110101641
5. chemistry.about.com/cs/howtos/a/aa052703a.htm
6. jchemed.chem.wisc.edu/Journal/Issues/1995/Jul/abs652.html

1-5 Reactions in the Real World

Outcomes:

1. Represent chemical reactions and the conservation of mass, using symbolic equations. (321-1, Part 1)
2. Represent chemical reactions and the conservation of mass, using balanced symbolic equations. (321-1, Part 2)
3. Observe the simple decomposition of water in a lab setting. (ACC-X)
4. Identify new questions and problems that arise from what was learned, such as problems arising from obtaining hydrogen gas (a possible fuel) from water. (210-16)
5. Identify and describe science and technology-based careers related to the study of chemistry, namely thermite welder or underwater welder. (117-1)

Introduction

As we have seen back in the *"From Alchemy to Chemistry"* module at the beginning of the unit, chemistry isn't done by just mixing up a bunch of chemicals to see what happens. Imagine mixing two chemicals together without thinking twice about it. Chances are, one of three things will happen: 1) you'll get lucky and get a neat, interesting product, or, 2) nothing happens, but you're left to clean up the mix and do the lab dishes, or, 3) the whole thing blow up in your face; if you're lucky you haven't managed to hurt yourself or anyone else.

So chemical reactions can't just be left to good or bad luck - a good chemist tries to ***predict the products*** of a reaction before even trying to do it. After all, no one wants to do any more dishes in this world than he/she has to, and it's all fun and games until someone loses an eye. This module will go through the five standard reaction types, and will show how some of these reaction types have been used in the past and present.

Reaction Type 1: Simple Composition Reactions

Simple composition reactions are also known as "simple combination" or just "synthesis" reactions. In general, elements "A" and "B" make the new compound "AB." We can write this in two ways:

$$\textit{element} + \textit{element} \rightarrow \textit{new compound}$$

or

$$A + B \rightarrow AB$$

Chemistry-wise, this reaction contains the simplest reactants possible - two elements.

When metals burn in air, some amazing light shows can happen. Back in the *"From Light Bulbs to Fireworks"* module we saw that the intense, bright white and yellow light of fireworks is due to either burning aluminum, magnesium or iron in air.

Remember that air is a mixture of gases: it is only the oxygen in air that reacts with each metal in the simple composition reaction.

For iron:

$$\underline{4}\ Fe(s) + \underline{3}\ O_2(g) \xrightarrow{\Delta} \underline{2}\ Fe_2O_3(s)$$

For magnesium:

$$2\ Mg(s) + O_2(g) \xrightarrow{\Delta} 2\ MgO(s)$$

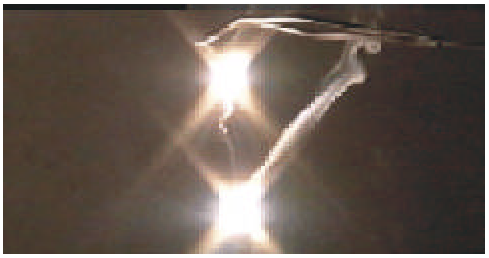


Figure 1. The simple composition reaction of Mg and O_2.[3]

The idea behind the simple composition reaction for aluminum is not only at work in fireworks, but also when aluminum cans and other containers are made. When aluminum is freshly refined, it is a very shiny grey metal, but almost immediately becomes duller in air. What happens is that the aluminum immediately reacts with the oxygen in air (simple composition) to form a coating of aluminum oxide all over the surface of the aluminum (this causes the metal to look 'duller'). This aluminum oxide coating is very tough, so tough that no other chemicals can get at the aluminum. For this reason, aluminum is used for pop cans, bicycles, and boats.[1]

Reaction Type 2: Simple Decomposition Reactions

Simple ***de***composition reactions are also known as just "decomposition" reactions. In their simplest form, decomposition reactions are truly a reverse of simple composition reaction. For the simple two-element compound "AB" we can write:

$$new\ compound \rightarrow element + element$$

or

$$AB \rightarrow A + B$$

Just as very few things are as simple as they look in the real world, *simple* decomposition reactions are very rare in the real world. Lots of chemicals do a decomposition, but to be as simple as to produce "element + element" is rare; most often, an "element + compound" forms. Since compounds are 'not as simple' as elements, any decomposition that produces a compound cannot be officially classed as "simple decomposition."

One reaction that is simple decomposition is the reaction of water into hydrogen and oxygen.

Water decomposition:

$$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$$

Like many simple decomposition reactions, this reaction does not occur on its own: you can't pour a glass of water from the tap and sit there to watch hydrogen and oxygen bubbles start to form out of the blue. Since water is a stable compound, you have to put energy (such as electricity) into a sample of water to get it to decompose. This can be done with an "H" shaped tube of water with stick pins as electrodes coming out the bottom. Hooking up the electrodes to a 9V battery will get the electrolysis going.

The experiment is not something you'd see "in the real world" right now, but not too far in the future you may see the effects of this reaction. Electricity and water are fairly cheap (particularly in Newfoundland and Labrador!) while the fuels we use today (oil, gasoline) are much more expensive, by comparison. Now consider this: Hydrogen is a fuel. It has been used to send rockets to outer space for decades. Not only is hydrogen a lightweight fuel, it also "burns much cleaner" than oil or gas, which is much better for the environment. So, if we have lots of water and somewhat cheap electricity in Newfoundland and Labrador, how important can using hydrogen as a fuel be for the province in the future?

Reaction Type 3: Single Replacement Reactions

Single replacement reactions are also known as "single displacement" reactions. Single replacement reactions always have an element and a compound as reactants, and a new element and a new compound are produced.

We can write this as:

$$\begin{aligned} &\textit{element} + \textit{compound} \rightarrow \\ &\qquad \textit{new element} + \textit{newcompound} \end{aligned}$$

or

$$A \;+\; BC \;\rightarrow\; B \;+\; AC$$

Single replacement reactions are common in chemistry. The way these reactions are easiest to understand is if you think of a line change in a hockey or basketball game. For a hockey game, only the goalie and five skaters are allowed on the ice. So, for another player to come onto the ice, a skater has to leave the ice and go onto the bench. In the reactions above, think of the 'element' as the new skater and the 'compound' as being the game on the ice. For the element (new skater) to come onto the compound (into the game), room has to be made in the compound. So, an element leaves the compound to make room for the new element. In the end, a new compound is made when the new element enters (just like a new line combination is made when a new skater enters the ice). The element that left the compound isn't destroyed; it is just now on its own (the skater who left the ice, who isn't on the playing line now).

One of the most important single replacement reactions in history even had its own name: the ***thermite reaction***. The thermite reaction is quite simple on paper:

The Thermite Reaction (an example of Single Replacement):

$$\underline{2}\ Al(s) \;+\; Fe_2O_3(s) \;\rightarrow\; \underline{2}\ Fe(l) \;+\; Al_2O_3(s)$$

To do this reaction is anything but simple. Look at the ***state*** of the iron that forms; it is "(l)," meaning ***liquid iron***. If we look at this reaction closely, it says that if we take aluminum powder and iron(III) oxide (the main compound of what we call 'rust') and simply mix them, we get enough heat produced to make molten iron (!) along with aluminum oxide as a 'byproduct'.

When railways were being first built in the 1800s and early 1900s all around the world, there was no such thing as portable welding machines. There was chemistry, though. The thermite reaction was useful in thousands of kilometers of railway around the world - the molten iron produced was used to

Figure 2. The thermite reaction at work.[4]

weld sections of rails together! The reaction is still used today in the railway industry, as the techniques for using it in welding have been refined and modernized by several companies. The reaction is also used in underwater welding, where using welding torches is not an option.[5]

Since single replacement reactions can 'free up' a metal from a compound (as done for iron in the thermite reaction), single replacement reactions are also commonly used in the mining industry to obtain pure metals from mined minerals.

Keep in mind that in single replacement reactions, it is the type of element that tells you how the reaction works. That means that if the element in the reaction is a metal, then it switches with the metal that was in the compound. In the thermite reaction, the element that reacts is aluminum - a metal. This takes the place of the metal (iron, Fe) that was in the **reacting compound (iron(III) oxide, Fe_2O_3)**.

This means that ***if the element in the reaction is a nonmetal, then it switches with the nonmetal that was in the compound.*** This is shown in the next example of a single replacement reaction:

Obtaining Bromine (an example of Single Replacement):

$Cl_2(g) + \underline{2}\ NaBr(aq) \rightarrow Br_2(l) + \underline{2}\ NaCl(aq)$

The reacting element is chlorine, a nonmetal. This 'kicks out' the nonmetal that is in the reacting compound, meaning that the "Br" is removed from the "NaBr."

Sea water contains many kinds of 'salty' compounds, including NaBr. When chlorine gas is bubbled through sea water containing NaBr (as in the reaction above), then valuable bromine is produced.

Reaction Type 4: Double Replacement Reactions

Double replacement reactions are also known as "double displacement" reactions. Double replacement reactions always involve two compounds as reactants and two new compounds are always products. We can write this as:

compound + compound →
TWO new compounds

or

$MX + NY \rightarrow MY + NX$

Note that this is the first type of reaction we've seen where ***no elements*** are involved.

Double replacement reactions commonly involve solutions of the two reacting compounds, and one of the new compounds formed then ***precipitates***. This is shown in the next example.

Precipitating Iron Ions (an example of Double Replacement):

$FeCl_3(aq) + \underline{3}\ NaOH(aq) \rightarrow$
$Fe(OH)_3(s) + \underline{3}\ NaCl(aq)$

The reacting compound of interest is $FeCl_3$, iron(III) chloride. This compound, if it were present in your tap water, would cause a brownish-yellow colour and possibly even cause it to taste salty. It is quite common for water supplies (whether they are town water supplies or a well for a single home) to contain such ionic compounds. However, you do not want *too much* of these compounds in your water, colouring your water and ruining its taste.

The reaction given above would be a water test for iron(III) chloride. A sample of tap water is taken from a home, and a solution of sodium hydroxide (NaOH) is added to the water sample. If a gel-like orange precipitate forms, then this is proof that there is a lot of iron(III)-containing compound in the water.

Double replacement reactions also include ***acid-base neutralization*** reactions. If you or someone you know suffers from "heartburn," you are actually suffering from your stomach producing too much stomach acid. Stomach acid mainly contains hydrochloric acid (HCl(aq)). To get rid of the pain of too much HCl(aq) in your stomach, you can take something like Tums® - which contains the base calcium carbonate, $CaCO_3(s)$. The neutralization reaction of the acid (HCl(aq)) with the base ($CaCO_3(s)$) is shown below.

Acid-Base Neutralization (an example of Double Replacement):

$\underline{2}\ HCl(aq) + CaCO_3(s) \rightarrow$
$CaCl_2(aq) + H_2CO_3(aq)$

Note that the product "$H_2CO_3(aq)$" that forms quickly decomposes into water ($H_2O(l)$) and carbon dioxide ($CO_2(g)$) immediately upon forming, so if you place Tums® into acid, bubbles of carbon dioxide gas are immediately seen.

Reaction Type 5: Hydrocarbon Combustion Reactions

Let's break the term "hydrocarbon combustion" into the two parts - "hydrocarbon" and "combustion" to figure out what it's all about.

Let's also start with "combustion." The term "combustion" means "burning." Oxygen is required for a fire to burn, so "$O_2(g)$" is always a reactant for combustion. If a metal element is the other reactant, you have a situation where you have metal *element* plus oxygen *pure element*. Recognize this? When metal elements (such as iron or magnesium) are burned, the reaction may be classified correctly as EITHER "simple composition" or "combustion."

But it's not these metal combustion reactions that we are interested in now. We are interested in ***hydrocarbon*** combustion. Look at the word "*hydrocarbon*"; it is a compound containing only ***hydro***gen and ***carbon***. These compounds are some of the most common compounds in the world, and you have definitely seen hydrocarbon combustion reactions in your lifetime.

Propane, $C_3H_8(g)$, is a fuel used in barbecues, camping lanterns and plumbing torches. Other common fuels are hydrocarbons too. Butane, $C_4H_{10}(l)$, is found in cigarette lighters; gasoline has a high octane ($C_8H_{18}(l)$) content. So, if you've ever seen a propane torch, a barbecue or a cigarette lighter in action, you've seen a combustion reaction.

A complete hydrocarbon combustion reaction ALWAYS contains two reactants: a hydrocarbon and oxygen. The products are ALWAYS carbon dioxide and water vapour. This means we can write the general reaction as:

hydrocarbon + *oxygen* → *carbondioxide* + *water*

or

$$C_xH_y + O_2 \rightarrow CO_2 + H_2O$$

We can use this general form to write the reaction for burning propane, shown below.

Burning Propane (an example of Hydrocarbon Combustion):

$$C_3H_8(g) + \underline{5}\ O_2(g) \rightarrow \underline{3}\ CO_2(s) + \underline{4}\ H_2O(g)$$

Notice that since the hydrocarbon burns completely, it burns 'cleanly' - only carbon dioxide and water are produced. Larger hydrocarbons, like the compounds in paraffin wax ($C_{20}H_{42}$), may not burn as completely and 'dirty' smoke and soot products are often seen when these burn.

Figure 3. Hydrocarbon combustion: Paraffin wax ($C_{20}H_{42}$) fuels the flame.[6]

Conclusion

It isn't surprising to think of chemical reactions as occurring in a chemistry lab. We have seen in this module that not only can we classify many reactions into fitting into one of five different reaction types, but many of these reactions are used in the real world. Before putting away the module, check out the ***Activity*** section. There are easy-to-do lab experiments there, using materials which are either common in a chemistry lab or local stores. With the lab set up and using your time well, you could easily and safely complete all the reactions in a hour, and in the process see for yourself the five main types of chemical reactions in action.

Understanding Concepts

1. Look back to the simple composition reaction given for the reaction of iron with oxygen. What is the meaning of the "Δ" symbol above the arrow?

2. (a) Write the simple combination equation for aluminum with oxygen. (Hint: See the module for the correct name of the final product.) Make sure that you balance your equation.

   (b) Explain why there is no need to paint an aluminum boat with rust paint.

3. The following reaction is listed as a decomposition reaction in a science book:

   $\underline{2}\ NaClO_3(s) \rightarrow \underline{3}\ O_2(s) + \underline{2}\ HaCl(s)$

   Is this a simple decomposition reaction? Explain your answer.

4. (a) State the reaction for the simple decomposition of water.

   (b) List the basic steps in performing this decomposition by electrolysis.

5. (a) We read that a combustion reaction means "reacts quickly with oxygen." Write the combustion reaction for burning hydrogen. (Hint: The product is the most common compound in the world containing H and O.) Make sure that you balance your equation.

   (b) How is this reaction in part (a) related to the simple decomposition of water?

   (c) Based upon the combustion reaction for hydrogen you wrote in part (a), why do people say that hydrogen "burns clean" or is "an environmentally friendly fuel"?

6. Copper(II) sulfate solution ($CuSO_4(aq)$) is often used to kill moss in lawns. Galvanized nails have a zinc ($Zn(s)$) outer coating. When copper(II) sulfate is accidentally sprayed on exposed galvanized nails around the base of a house, the nails start to change colour.

   (a) What type of reaction is occurring?

   (b) Write the balanced chemical reaction.

   (c) As a homeowner, do you think it would be a good idea to be careful with spraying the $CuSO_4$ solution around the house, or would it be okay to be a little sloppy? Explain your choice.

7. The double replacement reaction is given for precipitating iron ions (the double replacement section). Which chemical formula is the "gel-like orange precipitate"?

8. A car battery contains sulfuric acid, $H_2SO_4(aq)$. A car accident on the highway just outside of town has sulfuric acid spilled all over the road, so the emergency response team on the scene sprinkles lime ($Ca(OH)_2(s)$) onto the road.

   (a) Which of the five reaction types will work to neutralize the acid spill.

   (b) Write a complete, balanced chemical reaction between the sulfuric acid and the lime.

9. Complete each hydrocarbon combustion reaction, such that the chemical formulae of all products are given and the whole equation is balanced:

   (a) $C_4H_8(l)$ burns in butane lighters:

   $\_\ C_4H_8(l) + \_\ O_2(g) \rightarrow ?$

   (b) $C_8H_{18}(l)$ burns in gas engines:

   $\_\ C_8H_{18}(l) + \_\ O_2(g) \rightarrow ?$

   (Hint: Whenever you balance a hydrocarbon combustion reaction, always balance the C and H atoms first; then, always save the O atoms for last. If necessary, double up all the numbers for the C and H balance before doing the O atom balance.)

Making Extensions

1. (a) Do research to find out devices which use hydrogen as a fuel.

   (b) Research and list some advantages of using hydrogen as a fuel.

   (c) Research and list some disadvantages of using hydrogen as a fuel.

2. Research the term "incomplete hydrocarbon combustion." Make a chart that compares complete hydrocarbon combustion to incomplete hydrocarbon combustion.

3. If complete hydrocarbon combustion produces only carbon dioxide (a clear, colourless gas) and water vapour, why do we see smoke coming from the back of cars even when high-octane (C_8H_{18}) gasoline is burned? State at least two reasons.

Activity **Name:** ______________________________

"Reactions in the Real World" - Five Reaction Types

Here are some lab examples of each of the five reaction types which are to be done by your teacher as a demonstration with the whole class. If done as a class lab, four stations could be set up and students could switch to a new station after 10-15 minutes. ***To obtain the predicted results at each station, students must FOLLOW the PROCEDURE ONLY.***

1. Simple Compostion

The Reaction of Iron (or Magnesium) with Oxygen.

Procedure:

1. Obtain some *steel wool*, about 5cm x 5 cm square. (Available from a local car supplies store (autobody department), hardware store (painting supplies) or grocery store (cleaning supplies).)
2. "Fan out" the steel wool so that it is, on average, only a few millimetres thick. ***Record how it bends and how it looks in the chart on your worksheet.***
3. IMPORTANT! Hold the steel wool in a pair of *lab tongs*... NOT YOUR HANDS!
4. Light a *Bunsen burner* or *plumber's propane torch*; turn off the lights in the room for full effect.
5. Using the tongs, hold the steel wool in the blue part of the flame. ***Remember to record your observations as you enjoy the show!***
6. IMPORTANT! After the reaction is over, compare the final product to some unburned steel wool. ***Record your observations and answer the questions for this section.***

Note: The same procedure (including Step 6) can be done with magnesium ribbon, but DO NOT LOOK DIRECTLY AT THE LIGHT PRODUCED. It is **intense**.

2. Simple Decomposition

The Electrolysis of Water.

Procedure:

The procedure is outlined in the module above. Note that very affordable apparatus may be obtained from common science supply companies. See Reference 2.

3. Single Replacement

The Reaction of Aluminum Foil with Copper(II) Chloride.

Procedure:

1. Get a piece of *aluminum foil* (as bought from a local grocery store), 5cm x 5 cm square). Break the foil into three or four smaller pieces. Do NOT ball up the pieces. Even though you have likely seen aluminum foil a thousand times before in your life, ***record your observations of this reactant.***
2. Get a *small beaker* (any volume between 100mL to 250mL) and add 75mL of tap water to the beaker.
3. Using a *lab scoop*, add two (rough) scoops of *copper(II) chloride powder* to the water and completely dissolve it by stirring with a *glass stir rod*. ***Record how this solution looks in your chart.***
4. Touch the sides of the beaker. ***In your chart, record*** whether the beaker feels ***"cold", "room temperature" or "warm"***.
5. Add the aluminum foil pieces to the copper(II) chloride solution. Stir until no more change occurs. ***Record how the reaction mixture looks now that the reaction is completely done.***

6. Gently touch the side of the beaker as the reaction continues. ***Record "cold", "room temperature" or "warm" now that the reaction is completely done.***
7. IMPORTANT! Strain off the solution down the sink and make sure all solid materials go in the garbage - NOT the drain.
8. Do the **Questions** that are found after the **Observation Chart** for this reaction.

4. Double Replacement

The Reaction of Solutions of Iron(III) Chloride and Sodium Hydroxide.

Procedure:

1. Obtain a *small beaker* (any volume between 150mL to 250mL) and add 50mL of tap water to the beaker. Use a small piece of *masking tape* to make an "iron(III) chloride, $FeCl_3(aq)$" label to stick on the beaker.
2. Using a *lab scoop*, add roughly one scoop of *iron(III) chloride powder* to the "$FeCl_3(aq)$" beaker and completely dissolve it by stirring with a *glass stir rod*. ***Record your observations of this solution in the chart.***
3. Obtain *another small beaker* (any volume between 100mL to 250mL) and add 50mL of tap water to this beaker, too. Use a small piece of *masking tape* to make a "sodium hydroxide, NaOH(aq)" label to stick on the beaker.
4. IMPORTANT: Sodium hydroxide is *corrosive*. DO NOT handle the pellets with your hands! Using a *lab scoop*, add *two pellets of sodium hydroxide pellets* to the "NaOH(aq)" beaker. ***Record your observations of this solution in the chart.***
5. Add the "NaOH(aq)" to the "$FeCl_3(aq)$." Stir the mixture using one of the *glass rods from before*. ***Record the appearance of the reaction mixture after the reaction in finished.***
6. Place ALL of the reaction mixture in the *dump beaker* provided. Rinse each beaker you used well with lots of water and wipe any remaining precipitate off of the beakers with a *paper towel*.
7. Do the **Questions** that are found after the **Observation Chart** for this reaction.

5. Hydrocarbon Combustion

The Combustion of a Paraffin Wax, $C_{20}H_{42}(s)$

Procedure:

1. Take a *paraffin candle* (available at a grocery store, department store or thrift shop) and light it.
2. Observe the candle that you have lit. In the observation chart, state whether the candle is "burning cleanly" or "not burning cleanly".
3. Blow out the candle. Clean up any mess and make sure that any matches are no longer burning or hot. DO NOT put any matches or mess in the lab sinks!
4. Do the **Questions** that are found after the **Observation Chart** for this reaction.

ACTIVITY WORKSHEET **Name:** ______________________________

"Reactions in the Real World"

Use this sheet to record your observations and write the answers to the questions for each of the five reaction types in the activity.

1. Simple Composition

Observation Chart:

Procedure Step	Observation
Step 2	Steel wool: How it bends and now it looks...
Step 5	Burning steel wool:
Step 6	Solid product found after burning the steel wool: Bends? Looks?

Questions:

1. (a) How is the product (made in step 6) different from the reactant metal (step 2)?

____

____

(b) What evidence for chemical change have you observed?

____

____

2. Write the complete, balanced chemical reaction that occurred.

____

2. Simple Decomposition

Observation Chart:

Procedure Step	Observation
Before connecting the (water containing cell) to the battery	
After connecting the (water containing cell) to the battery	

Question:

2. Write the complete, balanced chemical reaction that occurred.

___

3. Single Replacement

Observation Chart:

Procedure Step	Observation
Step 1	Aluminum foil:
Step 3	Dissolved copper(ll) chloride:
Step 4	Circle one: "cold" "room temperature" "warm"
Step 5	Appearance of reaction mixture:
Step 6	Circle one: "cold" "room temperature" "warm"

Questions:

1. List the evidence for chemical change which you have observed for this reaction.

___

___

___

2. Using the reactants (aluminum + copper(II) chloride), predict the products of the single replacement reaction and write a complete, balanced chemical equation.

___

4. Double Replacement

Observation Chart:

Procedure Step	**Observation**
Step 2	How the $FeCl_3$(aq) solution appears:
Step 4	How the NaOH(aq) solution appears:
Step 5	Appearance of the reaction mixture after the reaction is complete:

Questions:

1. List the evidence for chemical change which you have observed for this reaction.

2. Using the reactants (iron(III) chloride and sodium hydroxide), predict the products of the double replacement reaction and write a complete, balanced chemical equation.

5. Hydrocarbon Combustion

Observation Chart:

Procedure Step	**Observation**
Step 2	Circle one: "burning cleanly" or "not burning cleanly"

Questions:

1. List the evidence for chemical change which you have observed for this reaction.

2. (a) Explain why you chose “burning cleanly” or “not burning cleanly” in the observation chart.

(b) Based on the above, choose one: Did “complete combustion” or “incomplete combustion” occur for your specific candle?

(c) If you believe your candle is undergoing “complete hydrocarbon combustion”, write the balanced chemical equation for the process. If undergoing “incomplete combustion” then skip to part (d).

(d) Only do this section if you chose that “incomplete combustion” occurred. Products of incomplete combustion may include not only water vapour and carbon dioxide gas, but also carbon monoxide gas (CO(g)) and soot, or just carbon (C(s)). Balance the following skeleton reaction for incomplete combustion of paraffin wax.

$$\_\_\_\ C_{20}H_{42}(s) + \_\_\_\ O_2(g) \rightarrow \_\_\_\ H_2O(g) + \_\_\_\ CO_2(g) + \_\_\_\ CO(g) + \_\_\_\ C(s)$$

Concise Conclusion

Make a short summary statement about how a chemical reaction may be identified and any other short comments you may wish to add.

References

1. F. Jenkins *et al*. *Nelson Chemistry (Atlantic Edition)*, Nelson Canada, Toronto, 1996.
2. Check the Boreal Laboratories catalogue for item WW6934200 “*Low-Cost Electrolysis Apparatus*.” Also available at www.boreal.com.
3. www.angelo.edu/faculty/kboudrea/demos/burning_magnesium/burning_magnesium.htm
4. www.thermitwelding.demon.co.uk/profile.html
5. www.ilpi.com/genchem/demo/thermite/#demo
6. www.saskschools.ca/curr_content/chem30/modules/module3/lesson4/inqheatcom.htm

1-6 Chemistry at Work

Outcomes:

1. Provide examples of how science and technology are an integral part of their lives and their community by investigating chemistry in the workplace. (117-5)
2. Represent chemical reactions and the conservation of mass, using chemical equations specific to the chemistry of lawn lime and baking. (321-1)
3. Apply and assess theoretical models for interpreting chemical reaction rates, as related to the career of professional baker. (214-6)
4. Identify and describe careers related to the chemistry they are studying (117-7)

Introduction

With the modules you have seen so far, we have already asked the question, "What in the World Is Chemistry?" From finding so many examples of chemistry in our day-to-day life, we even thought it would be better to ask "What in the World ***Isn't*** Chemistry?" In this module, we'll change our focus from chemistry in the home to chemistry at the workplace. We'll pick a few common jobs that you could get after high school, and show that it won't just be you working at the job - chemistry will be at work there, too.

Back to the Beauty Salon

We read in an earlier module how "permanent" hair dyes work. Nowadays, many beauty salons offer more than just hair care; many offer fingernail styling or tanning sessions.

Imagine if you or someone you know is working at one of these places. You would use products containing many, many chemicals each day at work with the customers. These customers may want to know what exactly is in the products you are using and if they are harmful. Also remember that these customers would only be coming to the salon every now and then; if you are working there every day, you would want to know ***for yourself*** exactly what you are working with and the safest way to work with these chemicals. So - whether it is for your customers or for yourself - it's a good idea to know about the chemistry at your work.

Since the earlier module looked at the hair dye side of a salon business in detail, we'll just look at another part of a salon business: nail care.

Nail Care

Not so long ago, the most common nail polish removers were based upon a solvent liquid called ***acetone*** (Figure 1).

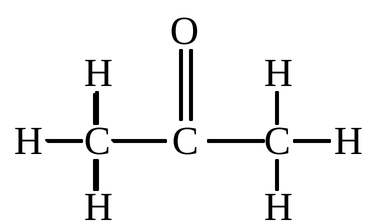


Figure 1. The acetone molecule, C_3H_6O.

While acetone was very good at removing nail polish, the strong smell of acetone was found to be more than many workers could handle after hours on the job. Health departments from governments around the world started looking a more closely at the long-term effects of working with acetone. Studies showed that when inhaled, acetone enters the blood and is carried to body organs. Short-term exposure (such as a full day at work) irritated workers' lungs, throat and eyes. Headaches, light-headedness, confusion and vomiting were also commonly reported. Long-term exposure (years of daily work) was reported to cause liver, kidney and nervous system damage, and was even thought to increase the risk of birth defects.[1,2]

Figure 2. "Non-acetone" nail polish remover is now common, and does not have as strong an odour as "acetone" remover.[5]

Nowadays, acetone nail polish removers can still be found on the market (especially in professional salons) but are much less common. Most nail polish removers are "acetone-free", have weaker odours and do not irritate or absorb into our organs in the same way as the old "acetone" ones.

It does not matter if you use nail polish remover at work or at home, you can see the importance of being informed.

Whether you choose to use acetone-free or the acetone-containing product, using it for a short as possible in a well ventilated area is important. In December 2004, the Government of Canada made it law that all cosmetics sold as of November 16, 2006 must have every ingredient listed on the label. Health Canada also suggests that workers in the cosmetics field obtain their own copy of the *Cosmetic Ingredient Dictionary and Handbook*. This is so that if problems arise with using a certain cosmetic product, its ingredients can be quickly identified and the correct treatment can be made.[3]

While nail polish remover has been found to cause health problems, the nail polish itself is a source of problems. Many nail polishes contain a chemical called toluene, which has the same long term effects of acetone exposure.[1] Quite often it is toluene that gives nail polish that heavy, strong smell. Today, there are many nail polishes that do not use toluene at all and are easily removed from nails by relatively safe acetone-free nail polish remover.

You can see that it would be an advantage to know chemistry if you are working with cosmetics. Life is all about choice and you can make better, safe, choices at work with cosmetics if you are informed about the chemistry involved.

From Healthy Nails to Healthy Lawns

Landscaping and lawn care are popular jobs for both high school students in summer and students just after graduation. When it comes to doing the job right and getting that "golf green" look of a lawn, it means much more than just cutting the grass. Knowing the chemistry of soil and grass makes decisions on what lawn products to use easier. Like much of North America, the soil in Newfoundland and Labrador is acidic, commonly even below the pH of 5.5.[6] The ideal range for most grasses, landscape plants, and even vegetables to grow is around pH 6.0 to 7.5. This means that the natural pH of soils in this province has to be adjusted to give the best growing conditions.[7] Since our soil is ***acidic***, to make it more ***basic*** (increase the pH) we must add a ***base*** to the soil. It is also important that the base isn't too strong a base, or it will then make the soil ***too*** basic. This means that landscapers commonly use ***lime*** on lawns and gardens. Lime is actually the compound calcium oxide, CaO. When rain water hits the lime, CaO, it reacts slowly to form calcium hydroxide, $Ca(OH)_2$, a ***base***. As this is slowly produced (when it rains every now and then) the soil becomes more and more basic.

When a professional landscaper uses lime, he/she commonly tests the soil first to find the pH. He/she then can calculate the right amount of lime to be put on the grass and soil. To make the landscaper's job a little easier, some makers of lime will assume a slightly acidic soil pH (around 6.0, as commonly found in North America) and then give the amount of lime to add to a garden for this starting pH. This second method usually works fine in Newfoundland and Labrador.

While soil pH is important to get green grass growing, the element ***iron*** seems to be very important as well. “Soluble iron” is found in many lawn fertilizer sprays. It usually contains a solution of iron(II) sulfate, $FeSO_4(aq)$, which has a dual role in helping your lawn. For yellowed lawns, the iron(II) sulfate helps bring the deep “golf green” colour back. For lawns with a lot of moss, it removes the moss and allows grass to grow better.[10,11] If your grass is green and moss is your only problem, you may remember that “Bordeaux mixture”, containing copper(II) sulfate, was explained as a moss remover in an earlier module.

Figure 3. Lawn care: a job that has a direct link to chemistry.[9]

Again, as with using lime or any chemical, using “more” does not mean “better”. While iron(II) sulfate may ‘scorch’ the moss out of a lawn, too much of it may alter the soil chemistry and start to affect grass growth.

So, knowing some chemistry related to soil pH, lime and fertilizers, can take the guesswork out of being a landscaper. On top of this, don’t you think it would be good for business if you knew the chemistry behind the lawn products you use when a customer asks about them?

Cooking Chemistry

So you’re not interested in how your nails look and you don’t care if the grass is growing or not. Well, maybe you do enjoy good cooking or baking. Chemistry really is just cooking with chemicals. With chemistry, the reactants in an experiment are just like the ingredients of a cook’s recipe. So, if you are a cook, knowing some chemistry can get your recipes (your experiments) the best possible results. Here are a few places where chemistry and cooking meet.

Baking soda is a pure compound: sodium bicarbonate, $NaHCO_3$. (Note: you may also find a book calling it “sodium hydrogen carbonate”, since “hydrogen carbonate” and “bicarbonate” mean the same thing.) Many recipes use this

Figure 4. Check the label closely on a box of baking soda and you will find that it is pure "sodium bicarbonate."

compound to produce soft, fluffy cookies or breads. The “fluffiness” is actually produced by carbon dioxide gas, $CO_2(g)$. Once the ingredients for the recipe are all mixed, simply baking the mixture causes the $NaHCO_3$ to decompose, producing bubbles of carbon dioxide, $CO_2(g)$.

$$\underset{\text{baking soda}}{2NaHCO_3(s)} \xrightarrow{\Delta} \underset{\text{carbon dioxide}}{CO_2(g)} + H_2O(l) + Na_2CO_3(aq)$$

Yet, this is not the only way that baking soda, $NaHCO_3$, is used in baking. In terms of “acids and bases”, this compound is a base. Bases react with acids, sometimes giving off carbon dioxide gas. When the baking soda (base) is added to a food acid in the recipe, carbon dioxide does, in fact, form. If you know of a recipe that has baking soda, check it for a food acid. Common “food acids” in recipes are vinegar, yogurt, cream of tartar (stay tuned, more on this later) and lemon juice.

Figure 5. Food acids. From left to right: vinegar, cream of tartar, lemon juice and yogurt.[14]

Let's say a recipe for muffin batter uses baking soda and lemon juice. Since $NaHCO_3$ is a base and vinegar contains acetic acid, CH_3COOH, the two react to neutralize each other:

$$\underset{\text{baking soda}}{NaHCO_3(s)} + \underset{\text{vinegar}}{CH_3COOH(aq)}$$

$$\rightarrow \underset{\text{carbon dioxide}}{CO_2(g)} + H_2O(l) + NaCH_3COO(aq)$$

The only problem with this reaction is that it happens very quickly. As soon as the ***liquid*** vinegar comes into contact with the solid baking soda, all of the carbon dioxide is produced. This means that if the muffin batter sits around on the counter for a while before being put on the oven, the batter will actually go "flat", as the $CO_2(g)$ bubbles escape into the air. So, if you are a good cook, you don't let your recipes that use baking soda and vinegar sit around: get it in the oven for good results!

If you are a more relaxed cook, who doesn't want to race to get your muffins in the oven, you may choose to use ***baking powder*** instead of ***baking soda and vinegar***. Baking soda is not a **pure** compound; it is a ***mixture*** of corn starch, baking soda and a food acid called "cream of tartar". Baking powder usually comes in a cardboard cannister, while baking powder usually is found in a simple cardboard box (see Figure 6 below).

Figure 6. Baking soda (centre) has two active ingredients already mixed together when you buy it: baking soda (left) and cream of tartar (right).[16]

The corn starch is in there for a simple reason: to keep the other parts dry and to bulk up the mixture and make the baking powder easy to measure out. The baking soda part is still $NaHCO_3$, a base. "Cream of tartar" is a compound called potassium bitartrate, $KHC_4H_4O_6$. This compound is a ***solid acid***, and it reacts with the $NaHCO_3$ in the powder to (again) produce carbon dioxide bubbles:

$$\underset{\text{baking soda}}{NaHCO_3(s)} + \underset{\text{cream of tartar (acid)}}{KHC_4H_4O_6(s)}$$

$$\rightarrow \underset{\text{carbon dioxide}}{CO_2(g)} + H_2O(l) + KNaC_4H_4O_6(s)$$

The fact that the cream of tartar is a ***solid*** acid is the key idea. Back when we talked about baking ***soda*** and ***vinegar***, the reaction was ***very fast*** because the vinegar is a ***liquid*** which mixes quickly with the baking soda. This allows for a ***fast reaction and fast CO_2 bubbles.*** Now, with baking ***powder***, both the base ($NaHCO_3$) and the acid (cream of tartar) are ***solids***. Because they are ***solids***, they ***react much more slowly and produce CO_2 bubbles more slowly.*** This means that a recipe with baking ***powder*** in it ***will not go flat*** if it is left to sit on the counter. In fact, it will not even produce carbon dioxide bubbles until it is put in the oven, at a high enough temperature to get the baking soda / cream of tartar reaction going.[12,13,14]

Baking soda and baking powder are similar in name and are used for the same overall purpose - to make carbon dioxide bubbles and add 'fluffiness' to baked goods. Another reaction that is important to producing 'fluffy' bread is the reaction of yeast with sugar in bread dough. The reaction is shown below.

$$C_6H_{12}O_6(s) \xrightarrow{\text{yeast}} 2\,CO_2(g) + 2\,C_2H_5OH(l)$$

Yeast is actually a group of living organisms which is using the sugar to give it energy; carbon dioxide just happens to be a by-product. Like all living things, yeast needs certain conditions to survive and work well. The main condition to watch for healthy yeast growth is a warm temperature. Ask anyone who has ever tried to have his/her bread rise in a cold room: the yeast's chemical reaction goes too slowly, and not enough carbon dioxide gets produced to rise the dough.

Figure 7. The Perfect Loaf... thanks to knowing something about chemistry and reaction rates.[15]

So - what we know about reaction rates and temperature is completely related to getting that perfect loaf of bread.

We've seen three baking products that use chemistry to produce "fluffy" baked goods. These are often called "leavening agents" in a recipe. While baking powder, baking soda and yeast all produce carbon dioxide, they produce it in different ways, different speeds and in different amounts. A good baker, coming up with his or her own recipes, should know the chemistry behind each of the three leavening agents. This would allow the baker to get the right amount of leavening ($CO_2(g)$ bubbles) in a recipe and, more importantly for business, the tastiest product.

Just Where Do We End the Story?

In reading this module we have looked at three careers: salon work, landscaping and cooking, where chemistry is "at work." Before reading this, these jobs may have seemed to be in no way related to science class, yet this module has shown that there is chemistry involved every day at each job. We could easily go on to other jobs: why does a welder use an acetylene torch and not a propane torch? Why do professional cleaning products often have "ammonia free" stamped on them? When a painter chooses a paint, why is "latex" a better health and environmental choice over "oil" based paints? Again, we've only hit the tip of the iceberg in terms of chemistry in the workplace.

There is no way to tell all of these stories in a few pages of a single module. Hopefully, if we haven't hit on your choice of jobs, we've at least shown how your job could have chemistry related to it.

Notice how knowing chemistry "inside out" may not be important in getting the job done. Yet, to get the job done ***safely*** and ***well***, the more chemistry you know, the better. Chemistry at home. Chemistry at the workplace. What in the world isn't chemistry?

Understanding Concepts

1. (a) List the short term problems with using acetone containing nail polish remover.

   (b) List the long term problems with using acetone containing nail polish remover.

   (c) Imagine that you or a friend of yours was working at a beauty salon where the policy is to use acetone-containing nail polish remover because it is cheap and does the job well. What can you do to limit your exposure to the acetone?

   (d) What can your employer do to limit your exposure to the acetone?

   (e) Do you think you would be better off approaching your employer with the problem of acetone in nail polish removers? If so, what kind of options can you give to the employer for using other products?

2. Many nail polish removers today are based on a compound called ethyl acetate. Also, there are many nail polishes themselves that are made with ethyl acetate instead of toluene. State two reasons why you think it would be good to use a nail polish ***and*** a nail polish remover that are both made from ethyl acetate.

3. (a) Find in the module (or figure out on your own) the chemical formulae for:

   (i) lime

   (ii) water

   (iii) calcium hydroxide

   (b) Use these chemical formulae to write the balanced chemical equation for:

   lime + water $\rightarrow$ calcium hydroxide

   This is what occurs when rain water hits lime pellets on a garden. (You can look up Reference 8 for the answer and also find out a lot more 'lime' chemistry.)

4. A farmer in Deer Lake tests his soil and finds that it is around pH 5.0.

   (a) Would you suggest adding lime to the soil? Why or why not?

   (b) The farmer decides to lime the soil, but decides he wants to put on twice the recommended amount, "just to be sure he's got lots". Comment on whether you think using twice the recommended amount is a good idea or not.

5. Why do you think one recipe for a cookie can calls for just baking soda, but another recipe for a similar cookie call for baking soda and lemon juice?

6. A recipe for chocolate chip muffins calls for a teaspoon of baking soda and a tablespoon of vinegar. Estimate what the muffins would look like if a baker did the following:

   (a) used one tablespoon of baking soda and one tablespoon of vinegar

   (b) used one teaspoon of baking soda and one teaspoon of vinegar

   (c) used one teaspoon of baking soda and one tablespoon of vinegar.

7. A cornbread recipe calls for baking soda to be used in the batter and "then bake the batter at 400°F (200°C)." What do you think would happen if the baker set the oven temperature at:

   (a) 400°F

   (b) 400°C

   (c) 200°F

8. Grannie Gardiner makes her bread dough on a beautiful spring morning in April and sets it out in the sun by the window. Grannie Park comes over and complains it's too hot in the house and insists on opening the window. An argument starts up between the two grannies. Whose side are you taking? Use chemistry to explain who you are backing.

Making Extensions

1. In November 1995, Health Canada sent out a warning[4] to all Canadians that they should look at the packaging of their acetone-free nail polish remover. They listed several products that had non-child-proof caps that they believed should be thrown away because the product contained methanol (wood alcohol). If this acetone-free nail polish remover were safer than acetone-containing nail polish remover, why do you think Health Canada put out this warning? (Hint: You have to think back to where you saw 'methanol' in an earlier module.)

2. The next time you are in a drugstore which has a large cosmetics desk, survey the nail polishes to look for:

   1) if the ingredients are listed, and

   2) if toluene is a major ingredient, or

   3) if there are any nail polishes without toluene listed as an ingredient.

Also look to see if all of the nail polish removers at the store are acetone free.

3. Some beauty salons offer not only tanning beds, but also lotions that can be used for an artificial suntan. Most of the lotions on the market today contain what is believed to be a very harmless chemical called ***dihydroxyacetone***. Use the internet or the resource centre at school to find out more about this compound, and in particular why it is considered so safe.

4. Fertilizers often have a combination of three numbers stamped right on the bag, like "6-12-12." Use the internet or the school's resource centre to find out what these numbers mean and what elements are important to growing vegetables and flowers.

5. Use the internet or the school resource centre to search "chemistry" along with your chosen "career". Some careers you may want to consider are:

   (a) welding

   (b) painter

   (c) cleaner / janitor

   (d) photographer

Internet Resource

To observe videos of baking powder, baking powder and vinegar, baking soda and yeast in action to compare how they work to produce carbon dioxide, go to the internet link:

www.saskschools.ca/curr_content/paasurvey/foods10/mod3/lo3.3/leaveningagents.htm

Note that with simply the chemicals, a few glasses and some hot tap water, the same experiments may be performed in any kitchen.

Activity[17]

Baking is definitely a science. The science experiment given below produces an entirely edible product if the experiment is performed well. You may wish to do this experiment in your science lab or, even better, your school kitchen classroom. You should also consider not using the reactant "de-encapsulated legume meats" since there may be a person with severe de-encapsulated legume meat allergies in your school. This product goes very well with a "solution of water and bovine oil, emulsified with casein and lactose". Enjoy.

Experiment:

Production of a Heated Complex Mixture of Theobroma Cacao Chips in Primarily Gluten, Sucrose and Triglyceride.

Purpose:

To produce several fully heated samples of the mixture given in the experiment's title, with each sample being approximately 15g in mass.

Materials:

500 mL - partially hydrogenated tallow triglyceride (butter or margarine)

175 mL - crystalline sucrose (sugar)

175 mL - unrefined sucrose (brown sugar)

5 mL - 4-hydroxy-3-methoxybenzaldehyde (vanilla)

2 - calcium carbonate-encapsulated avian albumen-coated protein (eggs)

500 mL - gluten (flour)

5 mL - sodium chloride (salt)

5 mL - sodium bicarbonate (baking soda)

1 pkg - theobroma cacao (chocolate chips)

250 mL - chopped de-encapsulated legume meats (nuts) OPTIONAL. ALLERGY ALERT!

flat, rectangular aluminum metal sheets (baking sheets)
measuring spoons
measuring cups
mixing bowls

Procedure:

1. Cream the partially hydrogenated tallow triglyceride, methyl ether of protocatechuic aldehyde, crystalline and unrefined sucrose in a bowl.

2. Add the calcium carbonate-encapsulated avian albumen-coated proteins and mix well.

3. In a separate bowl combine the gluten, sodium chloride, and sodium bicarbonate. Add to creamed mixture.
4. Stir in theobroma cacao and de-encapsulated legume meats.
5. Place the final mixture in approximately 15g portions onto a flat sheet of aluminum (or other rigid, flat metal that can withstand high temperatures and cleans fairly easily).
6. Heat in an 190C (or 375F) oven for 8-10 minutes, to allow the chemical reactions to take place.
7. Remove from oven and place on cooling rack.
8. Serve samples warm, preferably with a tall glass containing a solution of water and bovine oil, emulsified with casein and lactose.

Analysis:

If several groups have performed this experiment, share samples and comment on the group which performed the experiment the best. Speak with all groups to try to understand why some group's experiment worked better than others.

References

1. www.lesstoxicguide.ca/index.asp?fetch=personal
2. www.cbc.ca/natureofthings/toxic_printable.html
3. www.hc-sc.gc.ca/english/media/releases/2004/2004_62.htm
4. www.hc-sc.gc.ca/english/protection/warnings/1995/78e.htm
5. shopping.msn.com/marketplace.aspx?pmpType=1&pcId=8004&catId=1047
6. res2.agr.ca/stjohns/ccomm/vol7_e.htm
7. www.organicgardening.com/feature/0,7518,s1-2-28-885,00.html
8. scifun.chem.wisc.edu/chemweek/Lime/lime.html
9. www.turfmanagementusa.com/services.htm
10. bryophytes.science.oregonstate.edu/page22.htm
11. www.unitedhomepages.com/articles/hi3-lawn-care-tips.html
12. www.familyeducation.com/pdf_display/0,4050,1-31047-1076,00.pdf
13. users.rcn.com/sue.interport/food/bakgsoda.html
14. www.saskschools.ca/curr_content/paasurvey/foods10/mod3/lo3.3/leaveningagents.htm
15. mypeoplepc.com/members/tvsmussel/sitebuildercontent/sitebuilderpictures/bread.jpg
16. www.courses.psu.edu/nutr/nutr119_aqc6/lab11/images/bakingpowder.jpg
17. www.cheminst.ca/ncw/experiments/echocochip.html