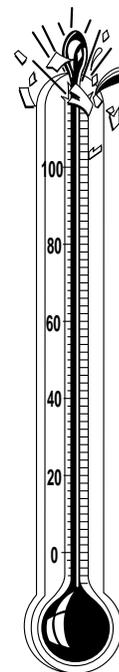
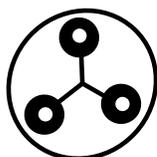




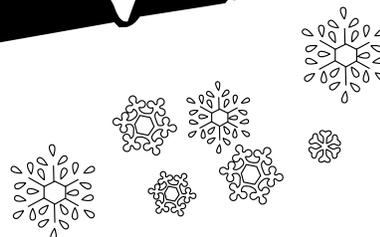
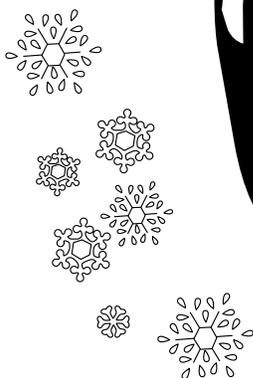
**HOT**



*and*



**COLD**

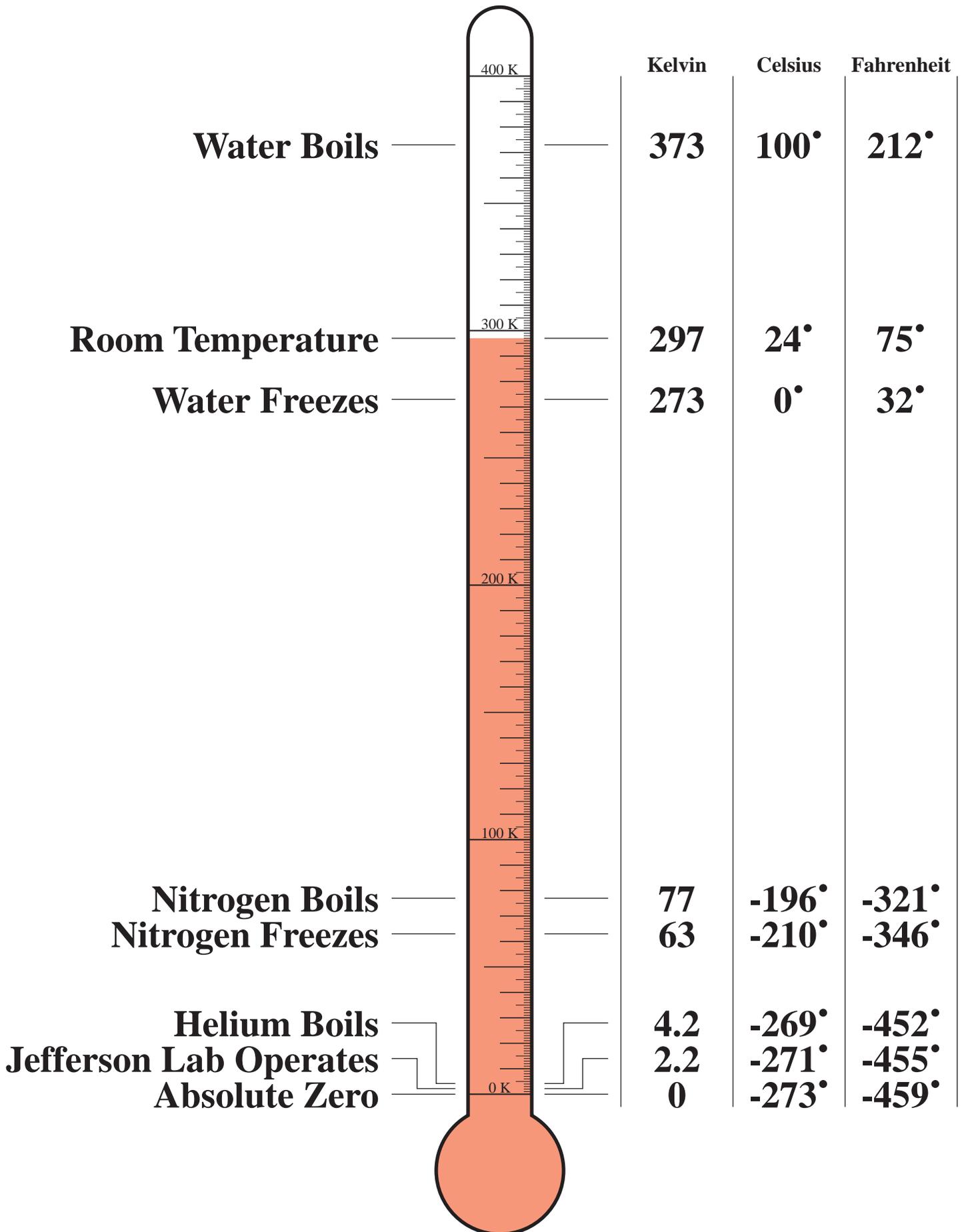


# ***Hot and Cold***

## **DO THINGS ACT DIFFERENTLY WHEN THEY GET REALLY HOT OR REALLY COLD?**

1. In this experiment, some things will be made very hot and some things will be made very cold. Use the chart on the next page to predict the outcome of some of the experiments. When a scientist makes an educated guess about an experiment, it is called a **hypothesis**.
2. Watch what actually happens and record the outcome in the chart.
3. Ask bunches of questions and have fun!

Experiment	What's your hypothesis?	What happened?	Why did it do this?
A balloon is filled with air and then made very cold. What will it do?			
A ping-pong ball is made very cold and then bounced. How will it bounce?			
A super ball is made very cold and then bounced. How will it bounce?			
A racquetball is made very cold and then bounced. How will it bounce?			
A burning match is slowly lowered into the vapor of a very cold substance. What will happen?			
A tube of Helium gas is heated to 3000° Centigrade (~5000° Fahrenheit). What will it look like?			



# Reading About Superconductivity

## JEFFERSON LAB'S ACCELERATOR CAVITIES ARE COOLED WITH LIQUID HELIUM TO BECOME SUPERCONDUCTORS.

In 1911 Heike Onnes, a Dutch scientist, was conducting experiments to learn how metals were affected by very cold temperatures. While working with the metal mercury, he discovered something new. When mercury was cooled to the extremely cold temperature of liquid helium, it allowed electricity to flow through it without any loss of energy.

Onnes and other scientists continued investigating other metals to learn if they would react the same as the mercury to the extremely cold temperature. They found that many of the metals had the same reaction. In one experiment, a metal wire loop was cooled in liquid helium and electricity was allowed to flow into the loop. When the source of the electricity was removed, the current continued to flow. Onnes was not able to explain this discovery, but he called it *superconductivity*.

In a normal conductor, the current stops flowing when the source of electricity is removed. If a superconducting metal is kept at the supercool temperature of liquid helium, the current can flow for years without becoming weaker.

It was many years before the discovery of superconductivity could be used in practical ways, because liquid helium and the equipment needed to cool superconducting materials are very expensive and difficult to handle. Today, the use of superconducting technology is being researched and applied in such fields as medicine, physics, transportation, communication and the military.

**Directions:** Answer the questions in complete sentences.

1. How many years ago was superconductivity discovered?
2. How could you test a metal to see if it is a superconductor?
3. How does a superconductor differ from a normal conductor?

**Bonus Question:** How are superconductors used in the cryomodules at Jefferson Lab?



Experiment	What's your hypothesis?	What happened?	Why did it do this?
A balloon is filled with air and then made very cold. What will it do?	<b><i>I think the balloon will pop.</i></b>	<b><i>It shrank.</i></b>	<b><i>The air in the balloon got so cold it turned into a liquid.</i></b>
A ping-pong ball is made very cold and then bounced. How will it bounce?			
A super ball is made very cold and then bounced. How will it bounce?			
A racquetball is made very cold and then bounced. How will it bounce?			
A burning match is slowly lowered into the vapor of a very cold substance. What will happen?			
A tube of Helium gas is heated to 3000° Centigrade (~5000° Fahrenheit). What will it look like?			

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**Directions:** Answer the questions in complete sentences.

1. How many years ago was superconductivity discovered?

***Current year - 1911 = 91 years in 2002, 90 years in 2001, etc...***

2. How could you test a metal to see if it is a superconductor?

***An electric current will continue to flow after the source of electricity has been removed.***

3. How does a superconductor differ from a normal conductor?

***An electric current will not flow in a conductor without a source for the electricity.***

**Bonus Question:** How are superconductors used in the cryomodules at Jefferson Lab?

***Jefferson Lab's Niobium cavities become superconductive when cooled with liquid Helium.***

# Hot and Cold

This is an activity in which students observe the effects of temperature extremes.

## Objectives:

In this activity students will:

- make predictions of the outcomes of several experiments
- observe experiments
- record their outcomes

## Questions to Ask:

1. How do you change a material from one state of matter to another?
2. Why did the three balls act differently?
3. How many states of matter are there?

## Travel Book Activities:

- Reading About Superconductivity
- Writing About Liquid Nitrogen

## Virginia State Standards of Learning

### Science 6.5 Matter

- by understanding that atoms are made up of electrons, protons and neutrons
- by understanding that atoms of any element are alike but are different from atoms of other elements

### Science 6.7 Matter

- by investigating and understanding that matter has physical and chemical properties and can undergo change

### PS.2 Investigate and Understand the Basic Nature of Matter

- by understanding the particle theory of matter

### PS.5 Investigate and Understand Changes in Matter

- by observing physical changes
- by observing changes in the state of matter
- by understanding the physical properties of matter

### PS.7 Investigate and Understand Temperature Scales, Heat and Heat Transfer

- by understanding the concepts of absolute zero, state change, freezing point, melting point, boiling point and vaporization

### PS.9 Investigate and Understand the Nature and Technological Applications of Light

- by understanding the electromagnetic spectrum

# Hot and Cold

## Teacher Overview and Materials List

### Background:

Jefferson Lab's acceleration cavities must be kept extremely cold if they are to operate properly. This is because a property of the Niobium metal the cavities are made from, called resistance, goes away if the temperature is low enough. This activity shows how some physical properties of other materials change if they are heated or cooled.

- Liquid Nitrogen is dangerous if not handled properly -

DO NOT attempt these demonstrations unless you have been properly trained in the safe use of Liquid Nitrogen

### Minimum Materials Needed for the "Cold" Demonstrations:

Several pairs of insulated gloves  
Several pairs of splash-proof goggles  
Assorted ladles and tongs  
5 liters (~1 gallon) of liquid nitrogen  
A 5 liter, narrow neck Dewar  
A 5 liter, open mouth Dewar flask  
Whistling tea kettle  
2 long stem carnations  
Matches  
2 long, skinny, semi-transparent balloons  
An empty 35mm Fuji film container with lid  
Ping-pong ball  
Solid rubber "super ball"  
Racquetball  
Pewter Jefferson cup

### Optional Materials:

Film container holder  
Metal sheet  
Clear plastic cup  
Candle  
Striking rod

### Notes:

- Use of a film container holder is highly recommended. Loose containers will leap into the air and spray any remaining nitrogen in unpredictable directions.
- Fuji film container lids snap into the container, acting like a cork. Kodak film container lids snap around the container and tend to fail at a particular point, allowing the nitrogen gas to escape without blowing the lid completely off.
- A video this activity (Deep Freeze) is available for loan through the Jefferson Lab Science Series Video Library.

### Detailed Directions:

1. Pour nitrogen on the floor and table.

**results:** White clouds of water vapor appear as the nitrogen chills the surrounding air below the dew point.

2. Pour nitrogen in a tea kettle.

**set-up:** Everyone knows that tea kettles whistle when they are hot. What happens when cold nitrogen is placed in it?

**results:** The tea kettle whistles if it is filled with boiling water. Since the room (and tea kettle) are far above the boiling point of nitrogen, the nitrogen rapidly changes to gas, causing the tea kettle to whistle.

**side experiments:** Is the tea kettle actually cold, or hot? Use a dark glove to wipe frost from the surface to the tea kettle.

Who wants to lick the kettle? Wet a cloth glove and stick it to the tea kettle.

Watch for liquid dripping from the kettle. This is air condensing onto the kettle. It is a mix of liquid oxygen and liquid nitrogen and should not be collected.

3. Put a flower into the nitrogen (2 volunteers).

**set-up:** Is it a good idea to put your hand in liquid nitrogen?

**results:** The water in the flowers freezes allowing the volunteers to crush the petals with their gloved hand.

4. Put a lit match into the nitrogen.

**set-up:** What happens if I put a lit match in the nitrogen? This is usually done in the mouth of the open mouth Dewar or in a small cup filled with nitrogen.

**results:** The match goes out as it passes into the Dewar. The Dewar is full of cold nitrogen gas. Since there is very little oxygen in the Dewar, the match can not remain lit.

**common answer:** Lots of people will say that it is too cold for the match to burn. Typically, the very top of the Dewar is around 20°F. A bit chilly, but not very cold.

5. Put an inflated balloon into the nitrogen (2 volunteers).

**set-up:** What happens if I put a balloon in the nitrogen? Lots of people think it will pop.

**results:** The balloon looks as if it deflated. The air within the balloon has condensed into a liquid and, since nitrogen contracts by about a factor of 1000 when it condenses, it can fit into a smaller volume. The balloon re-expands when taken out and could pop, depending on if some parts of the balloon are pinched off or are fatigued.

**common answer:** Many people say that the air has left the balloon. If so, there must be a hole for the air to leak out of. Since the balloon re-inflates, it can be shown that there is no hole in the balloon.

6. Put nitrogen into three film canisters and then close the lids.

**set-up:** I'm going to do the same experiment as the balloons, but in reverse. Instead of trapping air and making it cold, I'm going to trap the liquid and warm it up.

**results:** The film canisters will sit for a few seconds and then blow their caps off. It will do this with some force so make certain that no part of you is directly over the canisters. Since the nitrogen expands by a factor of 1000 when it boils, the internal pressure quickly builds to the point where the caps can't stay on.

7. Put a ping-pong ball, a 'super ball', and a racquet ball into the nitrogen (best NOT to let kids do this one).

**set-up:** Bounce each to see how they act while warm, then place each ball into the nitrogen. You need to wait about a minute before continuing with this experiment. You can start the next demo to make up the time.

**results:** The ping-pong ball is largely unaffected but can be broken if bounced hard enough (try to avoid this). A ping-pong ball is rigid to begin with. Freezing it just made it a little more rigid.

The super ball is rock hard and acts like a marble. It will bounce normally after it has warmed.

The racquet ball will shatter when bounced. Throw the ball away from the audience. Kids love to dive for pieces of the ball. You can give them some once they have warmed up enough.

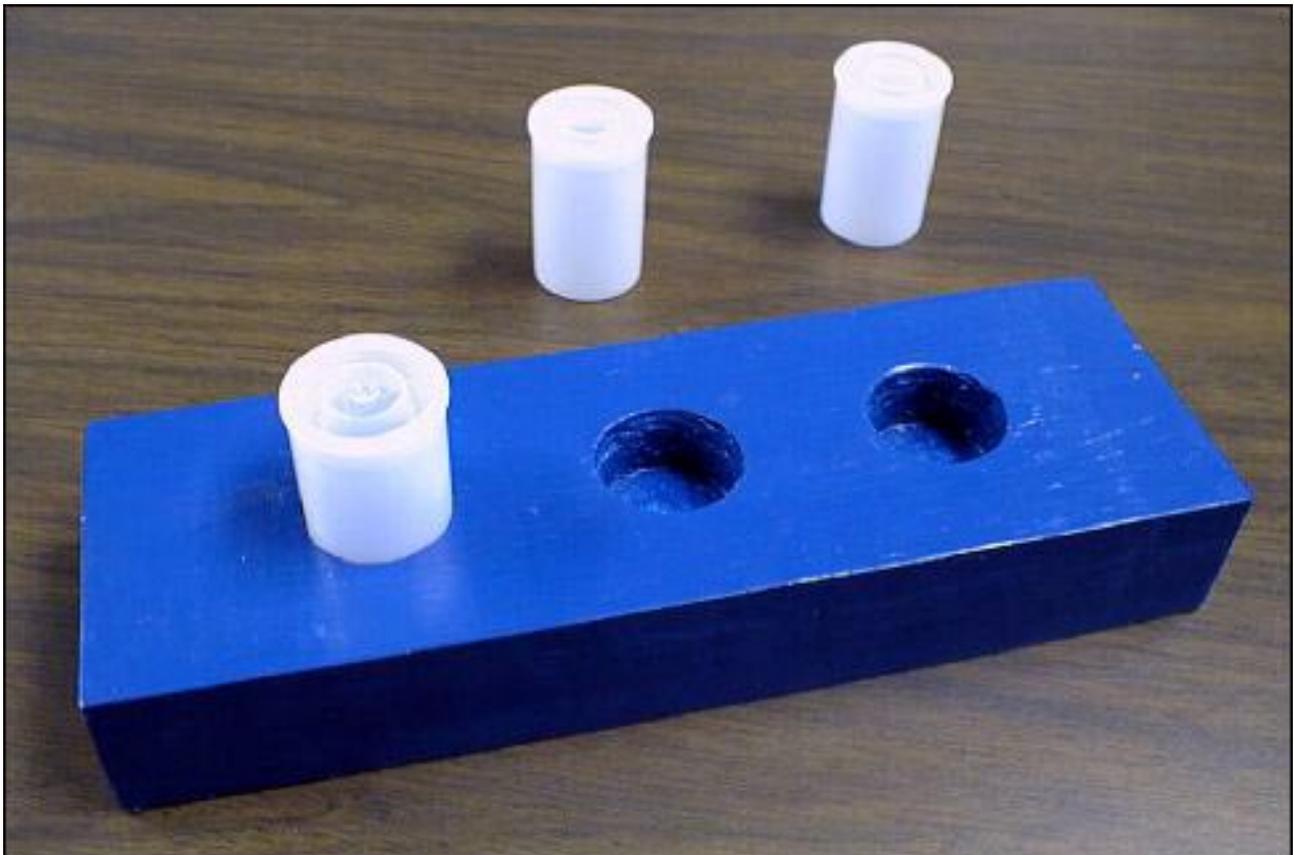
8. Make a lead bell.

**set-up:** Tap the Jefferson cup (pewter) to make it ring. Fill the cup with nitrogen to see if cooling it improves the quality of sound. The cup needs some time to cool down. You can finish the ball experiment while it cools.

**results:** The cup rings like a bell. Since pewter contains a lot of lead, it is very soft. Cooling the cup makes the cup more rigid which allows it to ring.



Materials for 'Cold'



A Film Container Holder

**Minimum Materials Needed for the “Hot” Demonstrations:**

Hand held Tesla coil  
A class set of diffraction grating glasses (Rainbow glasses)  
Florescent bulb  
Assorted spectral tubes  
Spectral tube holders

**Optional Materials:**

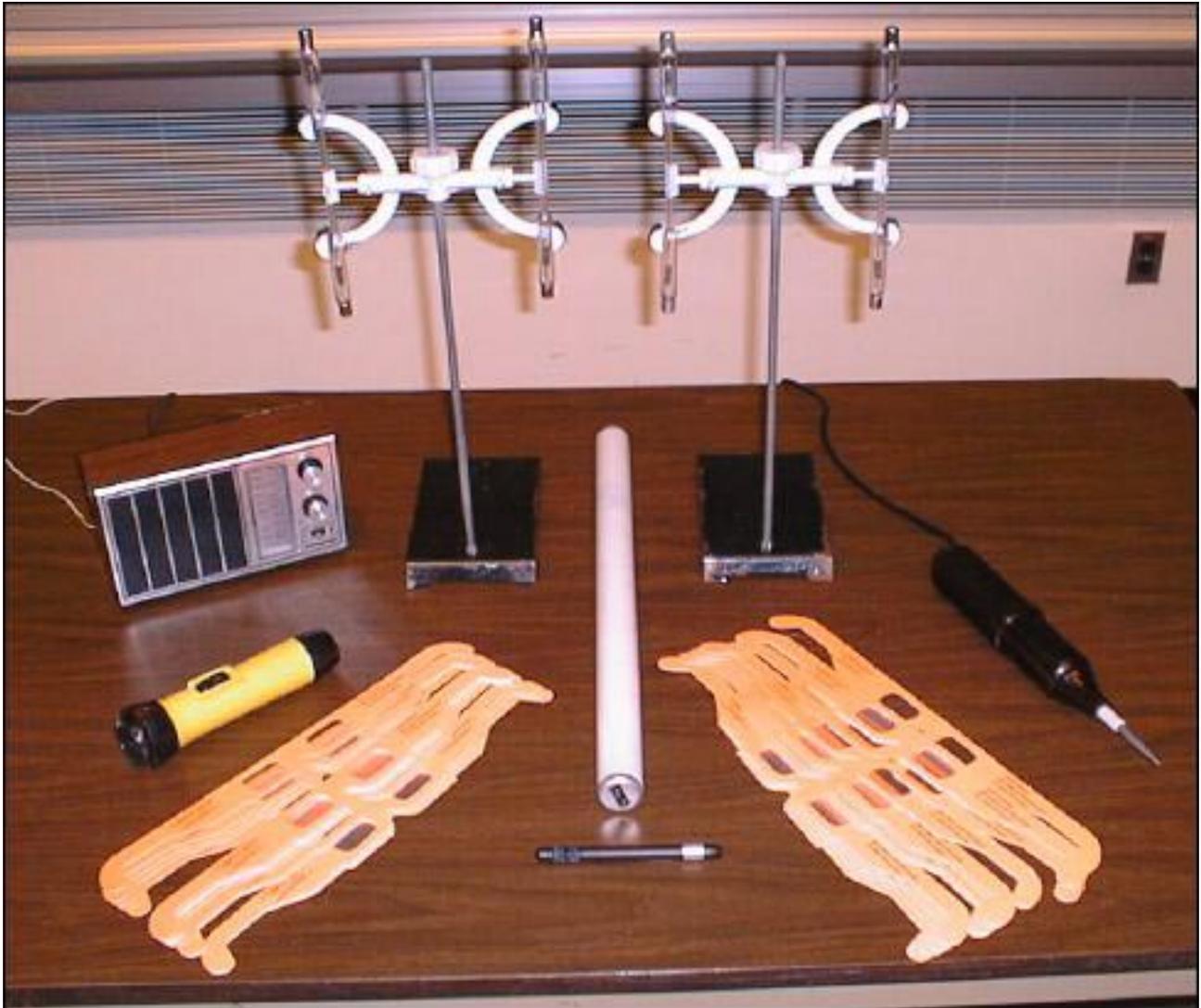
Flashlight  
Laser pointer  
AM radio

**Detailed Directions:**

1. Turn the classroom lights off and use the Tesla coil to activate the florescent bulb and the spectral tubes. Have the students pay special attention to the colors of the samples.
2. Turn the classroom lights on and give each student a pair of diffraction grating glasses. Observe the classroom lights and explain what the glasses are doing.
3. Turn the classroom lights off and once again use the Tesla coil to activate the florescent bulb and the spectral tubes. Have the students pay special attention to the differences in the samples' spectra.

**Notes:**

- When operating, the Tesla coil blankets AM radio frequencies with static. This can be observed with any nearby AM radio.



Materials for 'Hot'