Abstract

The critical superconducting temperature of a YCBO sample has been determined by three different methods. Except for visual observation, \( T_C = 99 \pm 0.5 \text{ K} \).

Magnetic Levitation:

One way to study high-temperature superconductivity is by studying its ability to repel magnets. A variety of rare earth magnets were set atop the YCBO disk at superconducting temperatures. When above the center of the disk, the magnet tended to spin and levitate stably. When near the edges, the magnet was repelled. The magnet also seemed to resist change in both spin and translational motion. As the disk was warmed past critical temperature, the magnet ceased spinning and levitating. Due to the precision from the voltmeter (± 0.1 mV), and due to the precision of the volt-temperature conversion chart (±0.5 K) [see attached], the error in temperature was about ± 5 K. After four trials, the critical temperature at which the disk became superconducting occurred at an average of 99 ± 5 K.

Resistance v Temperature:

The starting voltage was somewhat different than predicted in the manual. Instead of 0.3 mV at room temperature and 0.2 A, a measurement of about 1.5 mV was repeatedly obtained. Wire resistance problems were ruled out as the resistance across the wires was measured to be 0.134 \( \Omega \), which is much less than 1 \( \Omega \), and the voltage equipment was zeroed. Two different superconducting apparatus were tested with the same above results for each. Thus, it was concluded that resistance across the YCBO superconductor itself must have been higher than expected at room temperature. Proceeding with the experiment, the resistance was very near zero (0.0005 \( \Omega \)) as expected at superconductivity temperatures.

Due to the precision limitations of the instrument and the very small voltages being measured, the error in resistance is about ± 0.0005 \( \Omega \), and due to the precision of the voltage-temperature conversion chart [attached], the error in temperature is about ± 0.5 K. Thus, according to resistance, superconductivity occurred at about 90 ± 0.5 K.

Inductance v Temperature:

Four trials were conducted. All four sets agreed with one another. The fourth trial is being presented because it had the most data points. The impedance of the inductor measures the opposition to the sinusoidal AC current, i.e. it is proportional to the current frequency. The opposition is caused by the back emf, which is given by the rate of change of the magnetic field through the coil (rate of change of the magnetic flux). Thus, when the magnetic flux...
changes drastically due to the Meissner effect at superconducting temperatures, this change is reflected proportionally in the impedance (or inductance) of the coil.\(^3\)

Inductance was graphed using the impedance equation with \(\omega=2\pi[1\text{kHz}]\):

\[
\omega L = \left(\frac{V}{I} \right)^2 - R(T)^2 \right]^{1/2}
\]

As expected for an inductor, the impedance (and hence inductance) is imaginary.

When conducting the trials, a mean value was taken for the (AC) current and voltage. Because of the rapidness of the changing numbers and the necessity for a mean value, error for the current was \(\pm 0.05\) mA, error for the temperature voltage was \(\pm 0.01\) mV, and error for the inductance voltage was \(\pm 0.001\) V. Other error occurred in recording the measurements simultaneously, and in the precision of the volt-temperature conversion chart [attached]. A correction of these errors was attempted by refining the Drierite technique, taking multiple trials, and taking numerous data points for each trial. Also, due to similar problems with resistance as above, the resistance had to be normalized to be 0 \(\Omega\) at \(T_C\).

Taking into consideration only the chart and \(V_T\) error above, the critical temperature for the coil was \(90 \pm 0.5\) K.

**Susceptibility v Temperature:**

\(L_0\) was taken to be about .034 L, which was the warmest temperature point on the graph (128 K). \(f=0.858\) (the ratio of the volume occupied to the total volume in which the coil produces a field).

Susceptibility was thus graphed using the susceptibility equation:

\[
X = \frac{1}{f} L_0 - 1
\]

As expected, the susceptibility has the same shape and \(T_C\) as the inductance graph. In the superconducting region, the graph approaches values of -1, but the average is not quite -1.

**Attachments:**
Questions:

1. Superconductivity allows energy to flow through the metal without resistance below a certain temperature. Because it is very difficult to maintain such low temperatures outside of a lab setting, high-temperature superconductors are needed in order to use this phenomenon to more efficiently transmit energy for everyday applications (electricity storage, transmission, and generation, maglev trains, medical imaging, etc).¹

2. Near the edge of the disk we might be observing the fringe effects of the magnet. In addition, it was difficult to observe whether or not or where definite poles were on the disk.

3. I could not observe this effect even though I looked for it. Water molecules are polar molecules. Maybe what we are observing is condensed water vapor having been cooled by the liquid nitrogen and being attracted to the rare earth magnet.

4. Before the liquid nitrogen boils away, it envelops the disk in insulating nitrogen gas, thus shielding it from the air (and water vapor).

5. The transition in resistance at critical temperature is probably gradual because not all of the disk passes through critical temperature at the same time.

6. The susceptibility is slightly $<-1$ for temperatures below critical. As the manual says, this is due to neglected geometrical corrections.

7. Did not do magnetic field portion – 2 week lab.

8. One new use is the use of magnetic susceptibility probes in the treatment of cancer.²

¹ Source: Superconductors. <superconductors.org>
³ Source: Impedence. Wikipedia. <wikipedia.org/wiki/Electrical_impedance>

Volt-Temperature Conversion Chart (from CSI Manual):