"Synthesis of a $CeCoIn_5$ Single Crystal"

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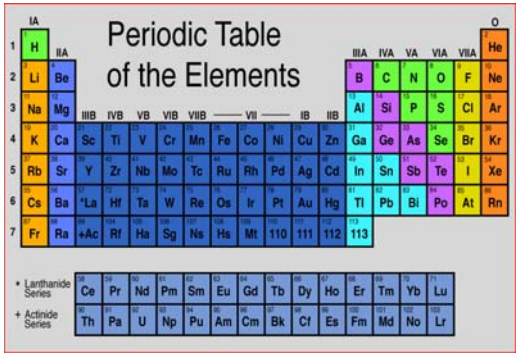
ABSTRACT

It was our purpose to synthesize crystals from the elements cerium, cobalt, and indium, using a 1:1:5 ratio, respectively. In order to synthesize the crystals, the metals were measured and encapsulated in an alumina crucible. The crucible was then inserted in a quartz ampoule, flushed with argon and vacuumed to remove any moisture, and sealed. The ampoule was then placed in a furnace, heated to 1150°C and held at 1150°C over a 24 hour period. The crystal was next cooled at the rate of 2.5°C/hour to 450°C at which point the ampoule was removed from the furnace and spun in a centrifuge to remove the excess flux and reveal the formed crystal. The synthesized crystal was finally used to study its superconductive and magnetic properties in a cryogenic environment.

WHAT ARE CRYSTALS?

Crystals are structures that are formed when atoms line up in an orderly formation, connect to each other by way of ionic or covalent bonds, and form a repeating pattern. Types of crystal systems include isometric, tetragonal, orthorhombic, monoclinic, triclinic, and hexagonal. Crystals are ever present in our daily lives, from common items such as ice and table salt to complex electronics, satellites, medicines, lasers, and military and space technology.

THE PERIODIC TABLE



Three elements from the periodic table were used to synthesize these crystals. From the Lanthanide Series, cerium, from column VII, cobalt, and from column IIIA Indium.

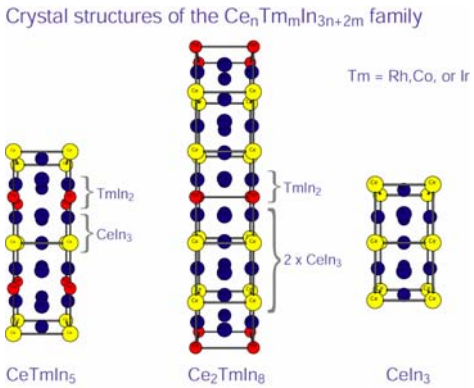
THE ELEMENTS

Cerium
Atomic Number 58
Atomic Weight 140.1

Cobalt
Atomic Number 27
Atomic Weight 58.93

Indium
Atomic Number 49
Atomic Weight 114.8

CRYSTAL STRUCTURE OF $CeCoIn_5$



PROCEDURE

Measuring the Metals

The first step in the synthesizing process is to measure the metals to form a 1:1:5 ratio. An arbitrary amount of cerium is used to begin the process (<1.0g). The metal is measured using a scale and then, when the weight of the cerium has been determined, it is entered in to a formula to find the weight of the cobalt and indium necessary for the 1:1:5 formation. The formulas are as follows:

To find the amount of cobalt needed:

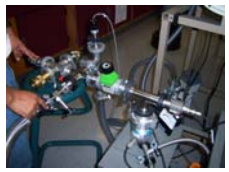
$$\frac{\text{atomic wt. Co}}{\text{atomic wt. Ce}} = \frac{(58.93)}{(140.1)} \times \text{actual wt. Ce}$$

To find the amount of indium needed:

$$\frac{\text{atomic wt. In}}{\text{atomic wt. Ce}} = \frac{(114.8)}{(140.1)} \times \text{actual wt. Ce} \times 30$$

Vacuuming and Flushing the Sample

When the appropriate amounts of cobalt and indium are determined, the three metals are combined in a small crucible, placed into an ampoule, vacuumed, and flushed with argon to remove any oxygen, water vapor, or other contaminants. Once the samples have been evacuated of contaminants, they are sealed using a mobile torch and placed into a furnace.

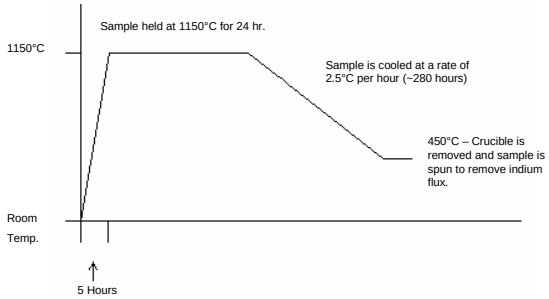


Preparing the vacuum for the ampoules.

The ampoules during their heating cycle in the furnace.

Heating and Cooling the Sample

Once the sample has been vacuumed and sealed within the ampoule, the ampoule is then placed within a large crucible (to hold it upright) and put in the furnace. The furnace begins at room temperature (~24°C) and is heated to 1150°C over the course of 5 hours. Once the sample has reached 1150°C, it is held at that temperature for 24 hours in order for the molten metals to meld together. After the 24 hour molten period, the sample is cooled to 450°C at a rate of 2.5°C/hour. This process takes roughly 280 hours to complete. The graph below is a pictorial representation of the heating and cooling process.



Revealing the Crystal

At 450°C the cerium and cobalt are already solidified and the indium has reached its eutectic point. It is at this time that the sample is removed from the furnace and spun in a centrifuge to remove the excess indium flux. Once the flux is spun off, the $CeCoIn_5$ crystal is revealed.

CONCLUSION

$CeCoIn_5$ single crystals are successfully synthesized using a self flux technique by combining stoichiometric amounts of cerium and cobalt with an excess amount of indium.

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REFERENCES

www.theodoregray.com (indium picture)

www.espimetals.com (cerium picture)

www.mme.cn (cobalt picture)

www.gpc.edu (periodic table picture)