DSE 1B CLASS

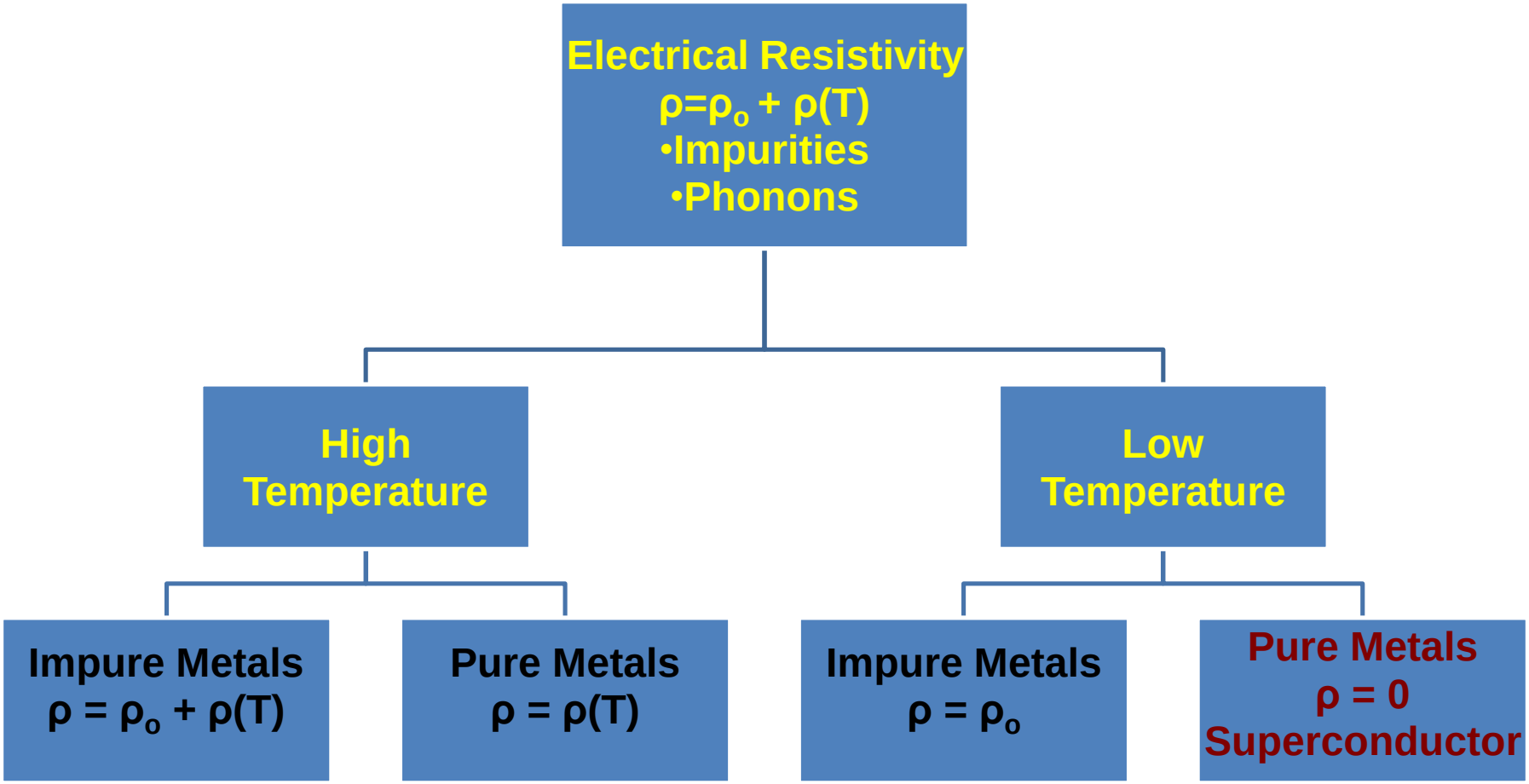
Lecture-1

3/09/2020

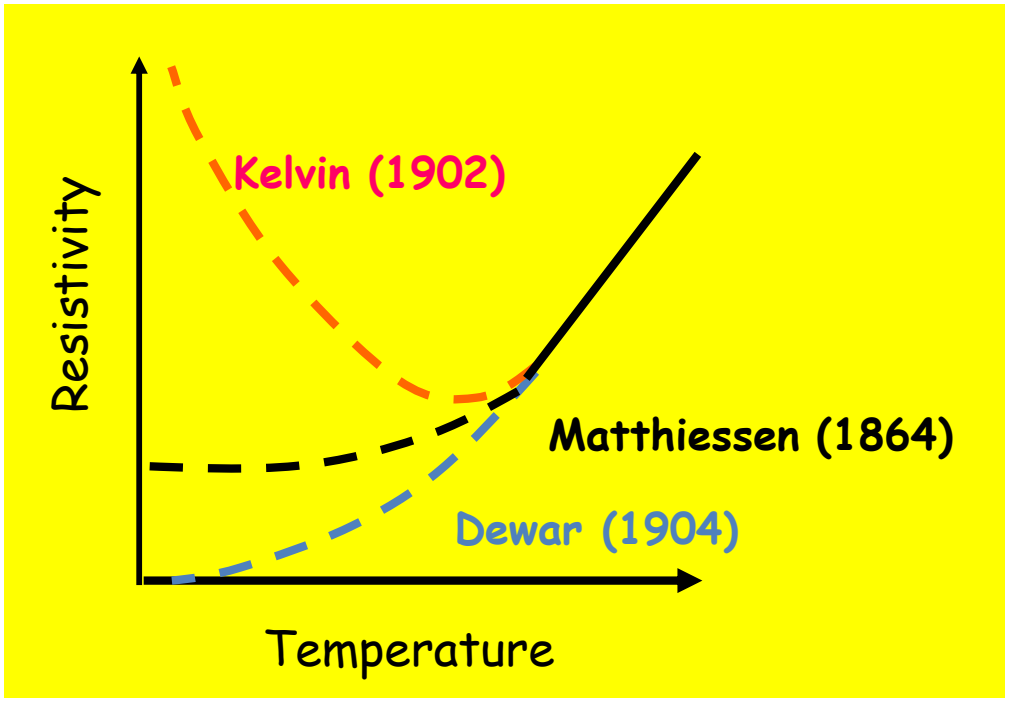
Definition

Superconductivity **is the flow of electric current without resistance in certain metals, alloys, and ceramics at temperatures near absolute zero, and in some cases at temperatures hundreds of degrees above**

Temperature Dependence of Resistance



What is the limit of electrical resistivity at absolute zero ?



Kelvin: Electrons will be frozen – resistivity grows till ∞.

Dewar: the lattice will be frozen – the electrons will not be scattered. Resistivity wiil decrese till 0.

Matthiesen: Residual resistivity because of contamination and lattice defects.

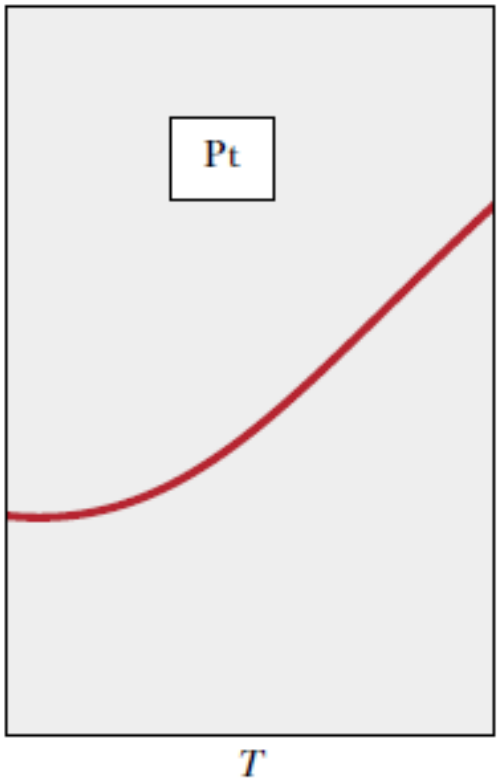
One of the scientific challenge at the end of 19th and beginning of the 20th century: How to reach temperatures close to 0 K?

1895 William Ramsay in England discovered helium on the earth

In 1908 the Dutch physicist Heike Kamerlingh Onnes first liquefied helium, which boils at 4.2 K at standard

The era of low-temperature phy

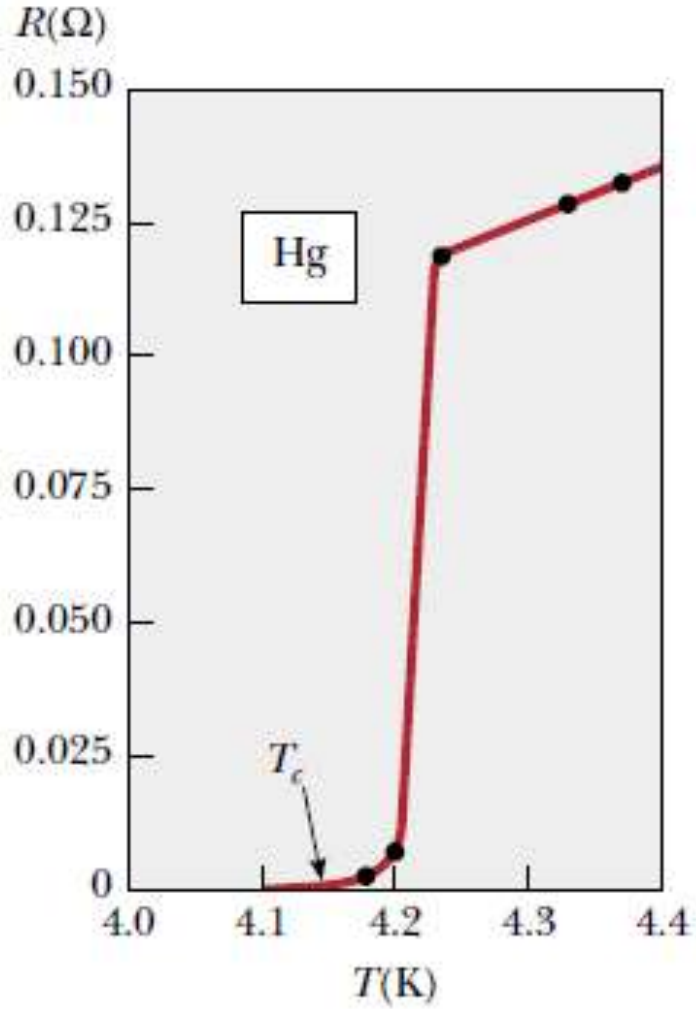
Kamerlingh Onnes and one of his assistants first studied platinum and found that its resistivity, when extrapolated to 0 K



They then decided to study mercury because very pure samples could easily be prepared

Onnes passed a current through a very pure mercury wire and measured its resistance as he steadily lowered the temperature.

Much to their surprise, the resistance of the mercury sample dropped sharply at



Discoverer of Superconductivity

- Superconductivity was first discovered in 1911 by the Dutch physicist,Heike Kammerlingh Onnes.
- In 1913 Kamerlingh Onnes was awarded the Nobel prize in physics for the study of matter at low temperatures and t liquefaction of helium.

- Source: Nobel Foundation

Soon after the discovery by Kamerlingh Onnes, many other elemental metals were found to exhibit zero resistance when their temperatures were lowered below a certain characteristic temperature of the material,

Transition Temperature or Critical Temperature (T_c)

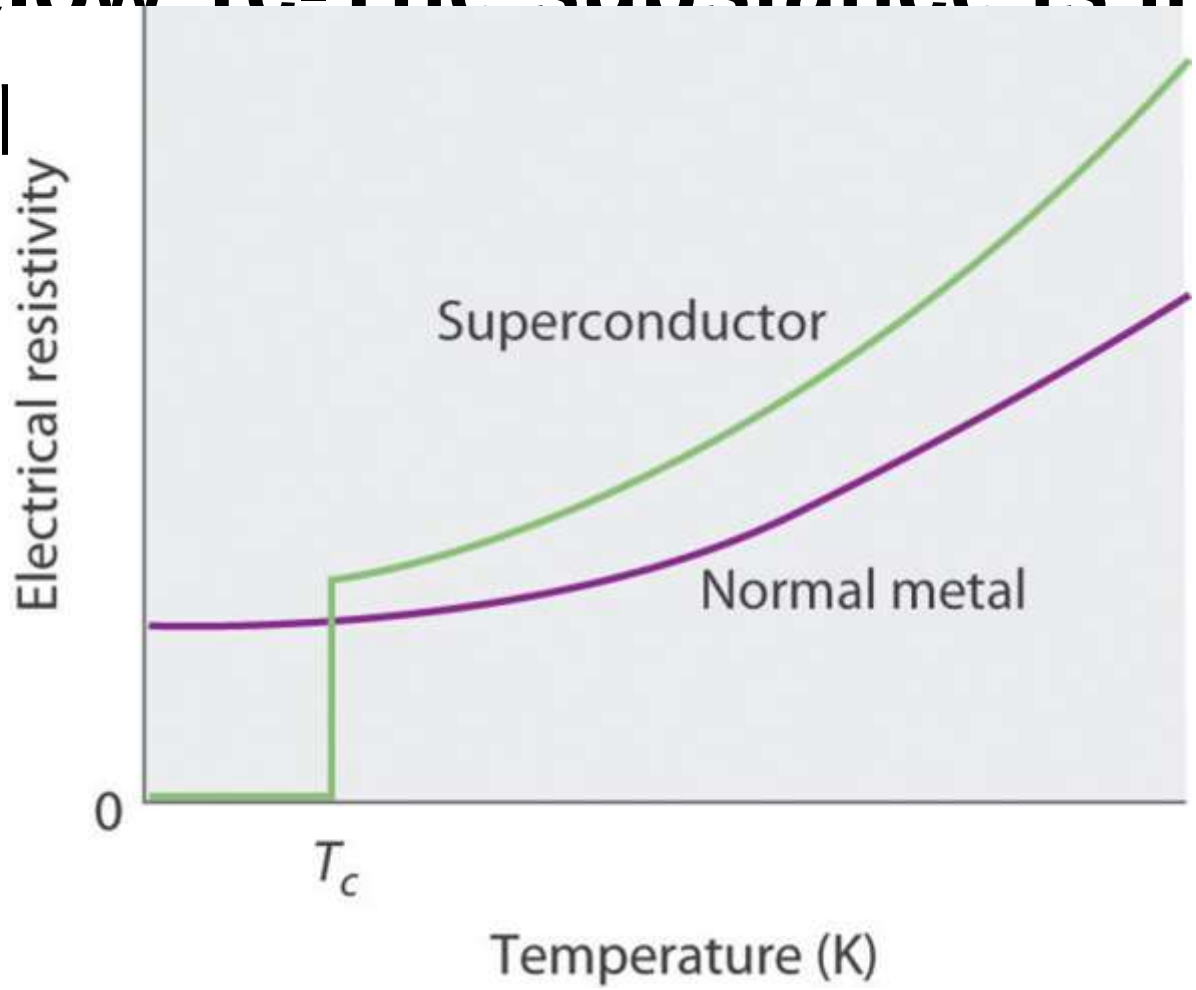
The critical temperature for superconductors is the temperature at which the electrical resistivity of a metal drops to zero.

Temperature at which a normal conductor loses its resistivity and becomes a superconductor.

The transition is so sudden and complete that it appears to be a transition to a different phase of

Above Tc- the substance is in the normal state,

Below Tc-The substance is in the su



- ✓ **Tc definite for a material**
- ✓ **Superconducting transition reversible**
- ✓ **Very good electrical conductors not superconductors eg. Cu, Ag, Au**

For semiconductors - Tc varies from, 0.3K to 1.25K

For metals - Tc varies from 0.35K to 9.22K For alloys

- Tc varies from 18.1K to 22.65K.

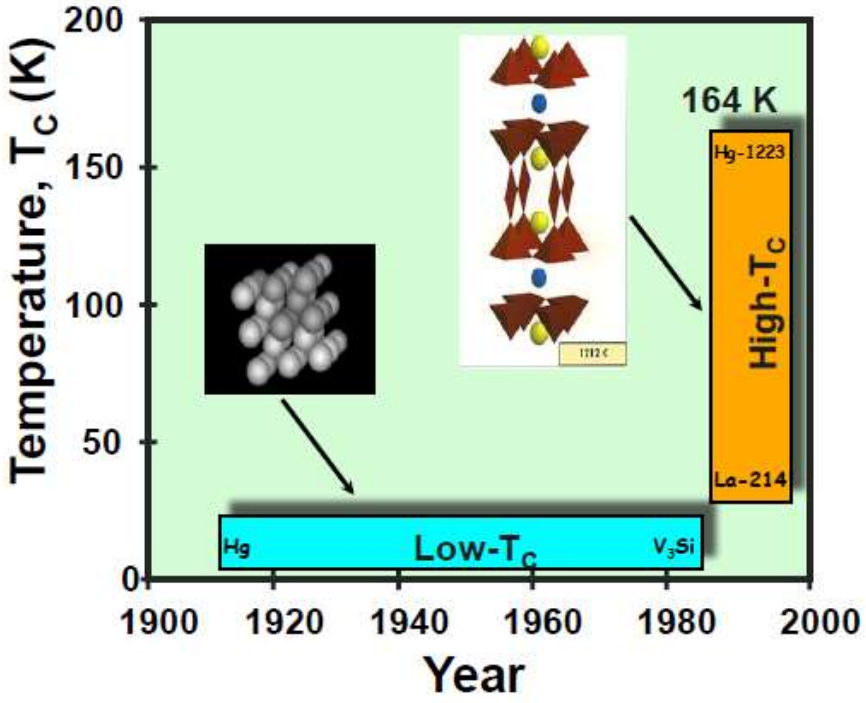
Occurrence of Superconductivity

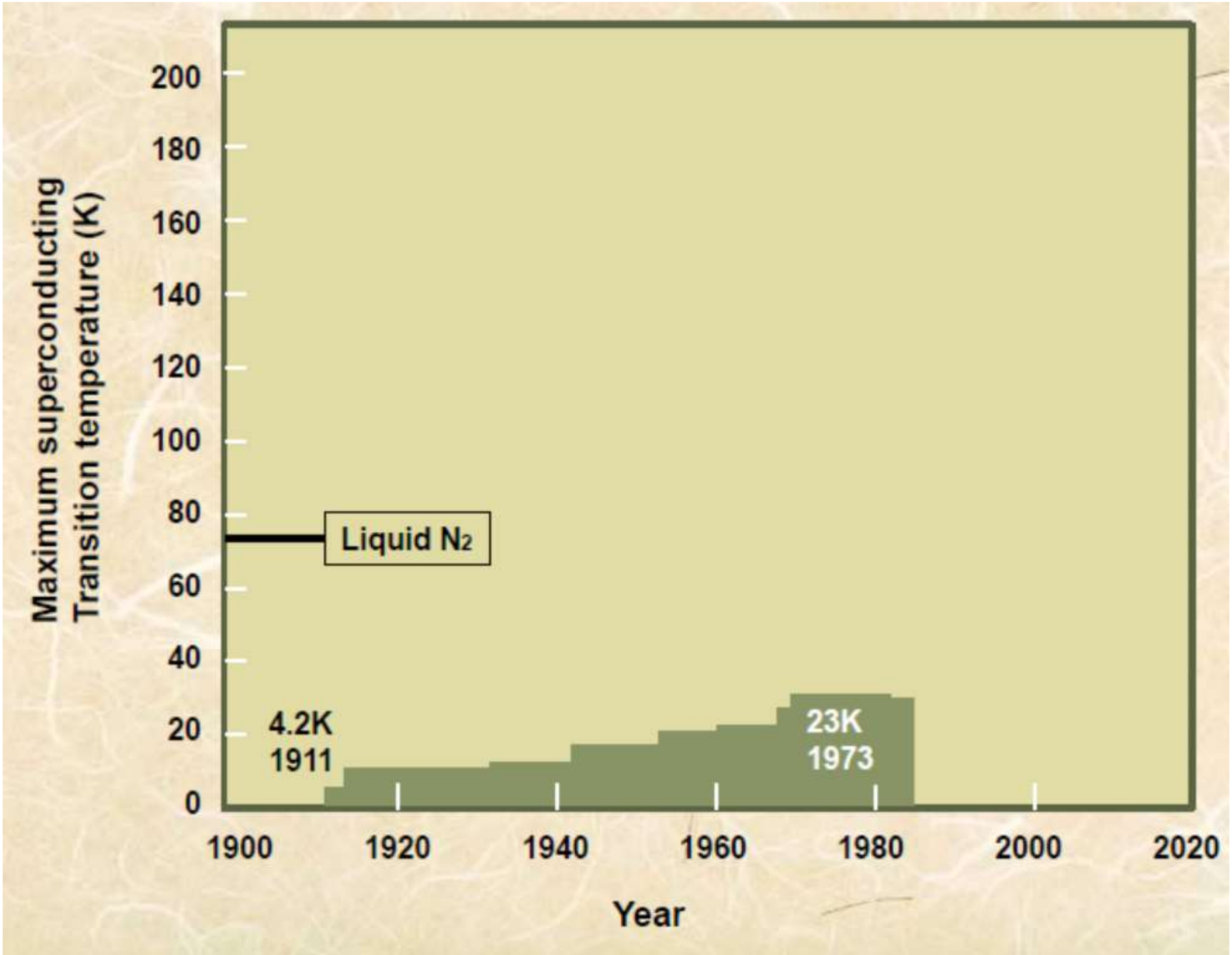
Superconducting Elements	**T_c (K)**
Sn (Tin)	3.72
Hg (Mercury)	4.15
Pb (Lead)	7.19
Superconducting Compounds	
NbTi (Niobium Titanium)	10
Nb_3Sn (Niobium Tin)	18.1

Types

Low Tc Superconductors

High Tc Superconductors




Maximum superconducting
Transition temperature (K)
200
180
160
140
120
100
80
60
40
20
0
Liquid N2
4.2K
1911
23K
1973
1900
1920
1940
1960
1980
2000
2020
Year

For many years, scientists have searched for materials that are superconductors at higher temperatures, and until 1986 the alloy **Nb3Ge** had the highest known critical temperature, **23.2 K**.

A Big Surprise came in 1986

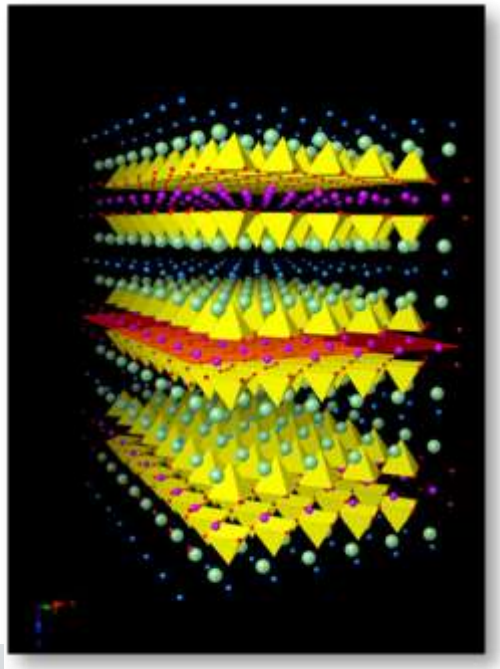
Bednorz and Mueller
IBM Zuerich, 1986

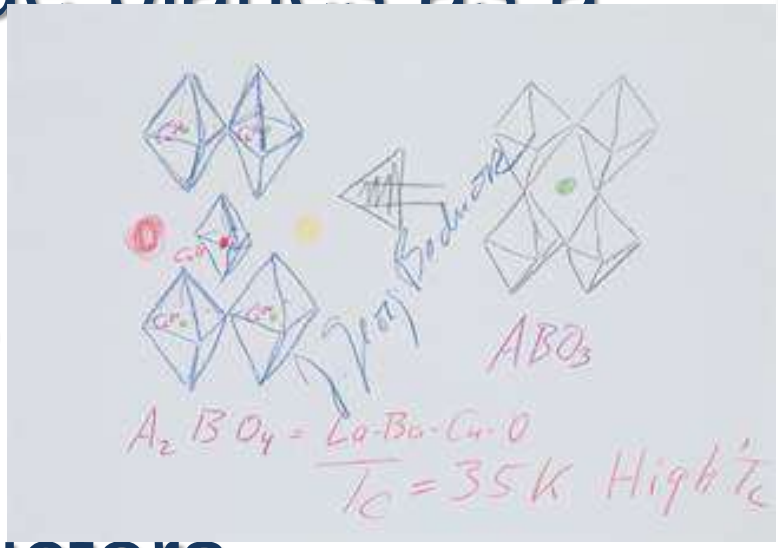
Won Noble Prize in 1987...for their important break-through in the discovery of superconductivity in ceramic materials

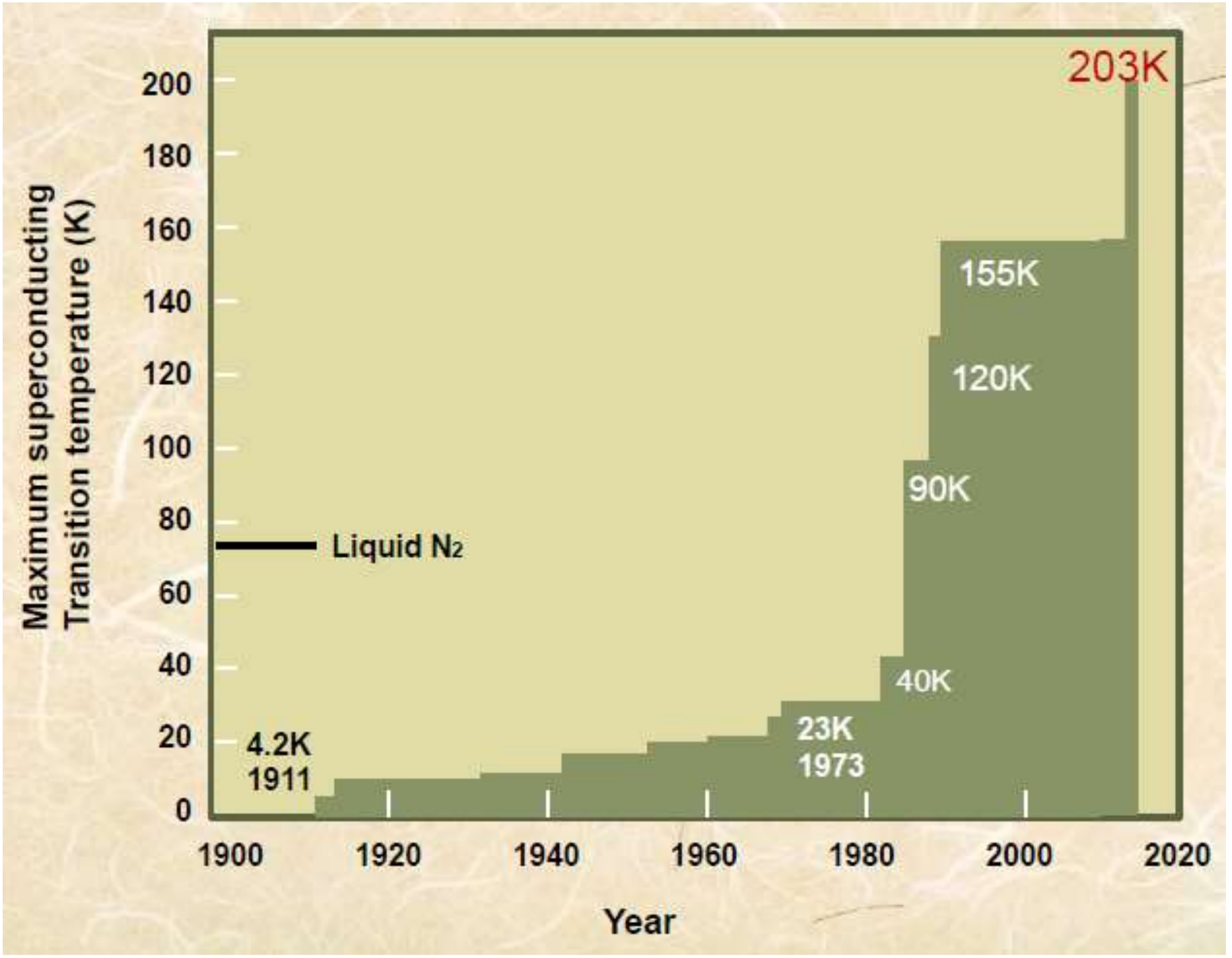
They discovered in a new type of materials, with T abnormally high

HIGH TEMPERATURE SUPERCONDUCTORS (HTS)

High-temperature superconductors are a family of superconducting materials containing copper-oxide planes as a common feature. They are cuprate superconductors






Maximum superconducting
Transition temperature (K)
200
180
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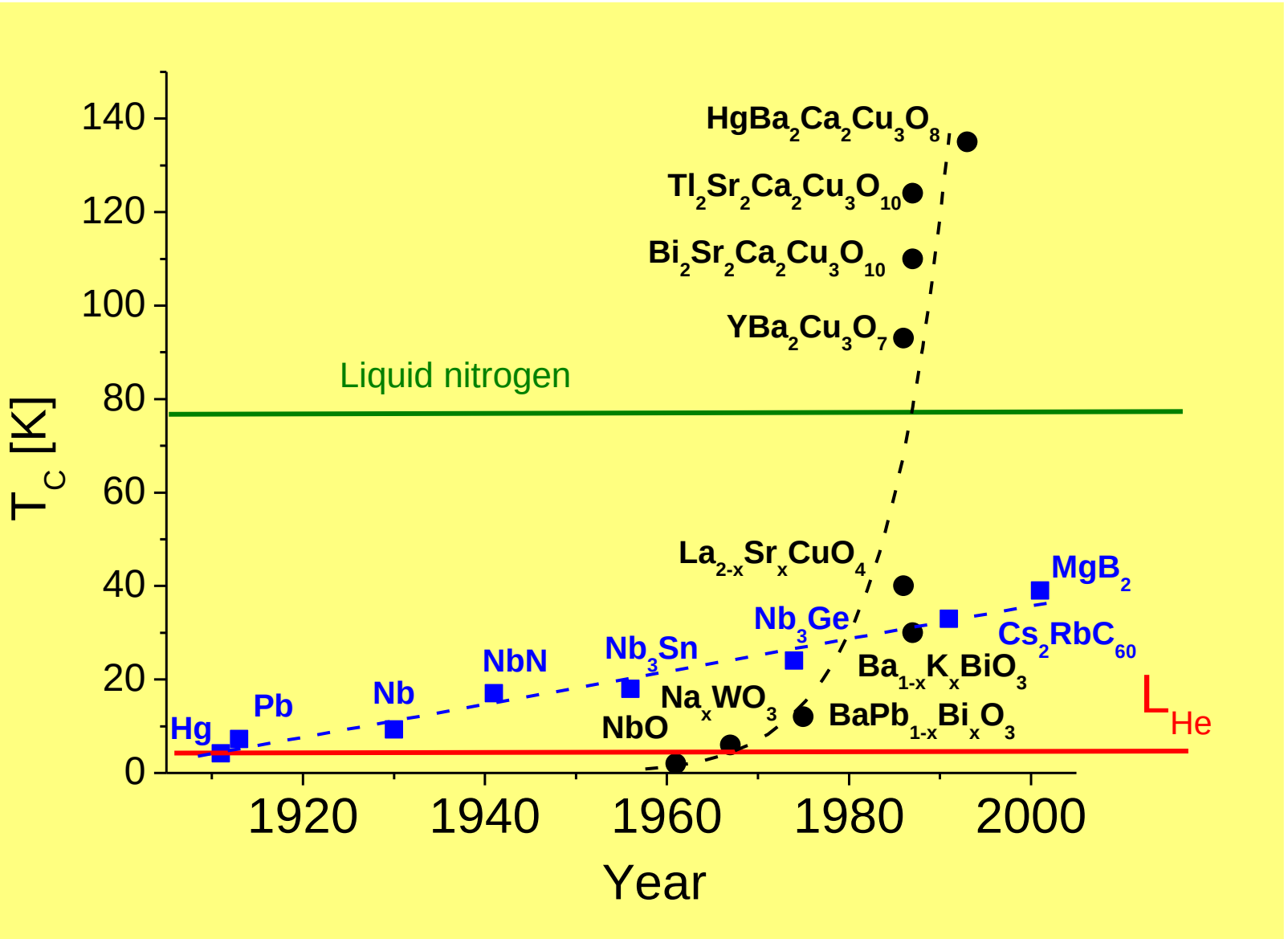
1900
1920
1940
1960
1980
2000
2020
Year
203K
155K
120K
90K
40K
23K
1973
4.2K
1911
Liquid N2


140
120
100
80
60
40
20
0
T_C [K]
1920
1940
1960
1980
2000
Year
Liquid nitrogen
$HgBa_2Ca_2Cu_3O_8$
$Tl_2Sr_2Ca_2Cu_3O_{10}$
$Bi_2Sr_2Ca_2Cu_3O_{10}$
$YBa_2Cu_3O_7$
$La_{2-x}Sr_xCuO_4$
MgB_2
Nb_3Ge
Cs_2RbC_{60}
Nb_3Sn
NbN
$Ba_{1-x}K_xBiO_3$
Na_xWO_3
Nb
Pb
Hg
NbO
$BaPb_{1-x}Bi_xO_3$
L_{He}

Further discoveries

1911-1986: "Low temperature superconductors" Highest T_C=23K for Nb_3Ge

1986 (January): High Temperature Superconductivity $(LaBa)_2\ CuO_4$ T_C=35K

K.A. Müller und G. Bednorz (IBM Rüschlikon) (Nobel preis 1987)

1987 (January): $YBa_2Cu_3O_{7-x}$ T_C=93K

1987 (December): Bi-Sr-Ca-Cu-O T_C=110K,

1988 (January): Tl-Ba-Ca-Cu-O T_C=125K

1993: Hg-Ba-Ca-Cu-O T_C=133K

(A. Schilling, H. Ott, ETH Zürich)

LETTER

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Superconductivity at 250 K in lanthanum hydride under high pressures

A. P. Drozdov[1,7], P. P. Kong[1,7], V. S. Minkov[1,7], S. P. Besedin[1,7], M. A. Kuzovnikov[1,6,7], S. Mozaffari[2], L. Balicas[2], F. F. Balakirev[3], D. E. Graf[2], V. B. Prakapenka[4], E. Greenberg[4], D. A. Knyazev[1], M. Tkacz[5] & M. I. Eremets[1]*

The race is on to make the first room temperature superconductor