LECTURE SCHEDULE

	Date		Topic
1.	Wed	28.10.	Course Introduction & Short Review of the Elements
2.	Fri	30.10.	Periodic Properties & Periodic Table & Main Group Elements (starts)
3.	Fri	06.11.	Short Survey of the Chemistry of Main Group Elements (continues)
4.	Wed	11.11.	Ag, Au, Pt, Pd & Catalysis (Antti Karttunen)
5.	Fri	13.11.	Redox Chemistry
6.	Mon	16.11.	Transition Metals: General Aspects & Crystal Field Theory
7.	Wed	18.11.	Zn, Ti, Zr, Hf & Atomic Layer Deposition (ALD)
8.	Fri	20.11.	V, Nb, Ta & Metal Complexes and MOFs
9.	Mon	23.11.	Cr, Mo, W & 2D materials
10	Wed	25.11.	Mn, Fe, Co, Ni, Cu & Magnetism and Superconductivity
11.	Fri	27.11.	Resources of Elements & Rare/Critical Elements & Element Substitutions
12.	Mon	30.11.	Lanthanoids + Actinoids & Pigments & Luminescence & Upconversion
13.	Wed	02.12.	Inorganic Materials Chemistry Research

EXAM: Thu Dec 10, 9:00-12:00 (IN MyCourses/ZOOM)

PRESENTATION TOPICS/SCHEDULE

Wed	18.11.	Ti: Ahonen & Ivanoff
Mon	23.11.	Mo: Kittilä & Kattelus
Wed	25.11.	Mn: Wang & Tran
		Ru: Mäki & Juopperi
Fri	27.11.	In: Suortti & Räsänen
		Te: Kuusivaara & Nasim
Mon	30.11.	Eu: Morina
		U: Musikka & Seppänen

QUESTIONS: Lecture 10

1. Most stable oxidation state in acidic conditions: Mn, Fe, Co, Ni, Cu ?

2. In which condition (acidic or basic) Cu^{+} tends to disproportionate ?

3. How many unpaired 3d electrons (oct./hs): Fe^{2+}, Fe^{3+}, Co^{2+}, Co^{3+} ?

4. Which one of the iron oxides, FeO, Fe_3O_4 and Fe_2O_3, is:
   - mixed valent
   - antiferromagnetic
   - ferrimagnetic
   - electrically conducting

5. Give the abbreviated name for $HgBa_2Ca_2Cu_3O_8$.

6. Oxidation state of Cu in La_2CuO_4, $La_2CuO_{4.1}$ and $(La_{0.9}Ba_{0.1})_2CuO_4$?

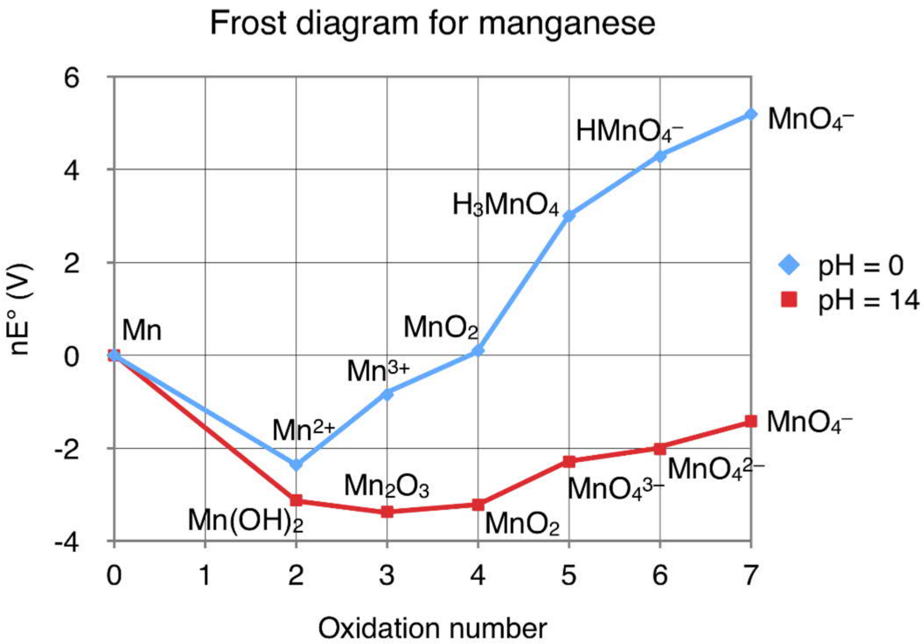
7. Are the above copper oxides superconducting ?

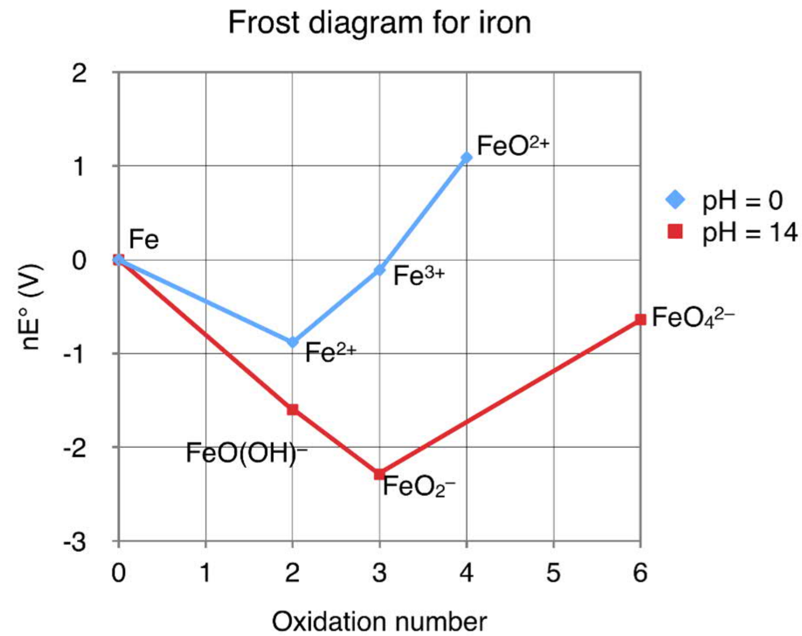
Group → / ↓Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
		*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
		**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

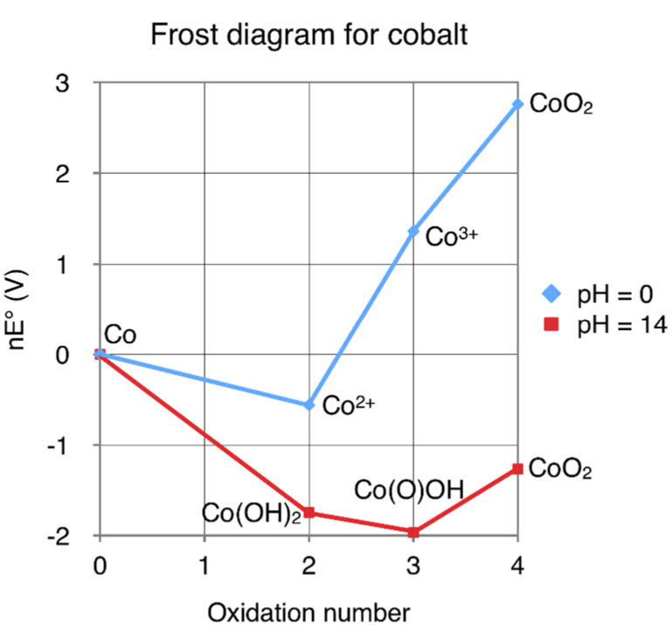
Element	**Symbol**	**Electronic Configuration**
Scandium	Sc	$[Ar]3d^1 4s^2$
Titanium	Ti	$[Ar]3d^2 4s^2$
Vanadium	V	$[Ar]3d^3 4s^2$
Chromium	Cr	$[Ar]3d^5 4s^1$
Manganese	Mn	$[Ar]3d^5 4s^2$
Iron	Fe	$[Ar]3d^6 4s^2$
Cobalt	Co	$[Ar]3d^7 4s^2$
Nickel	Ni	$[Ar]3d^8 4s^2$
Copper	Cu	$[Ar]3d^{10} 4s^1$
Zinc	Zn	$[Ar]3d^{10} 4s^2$

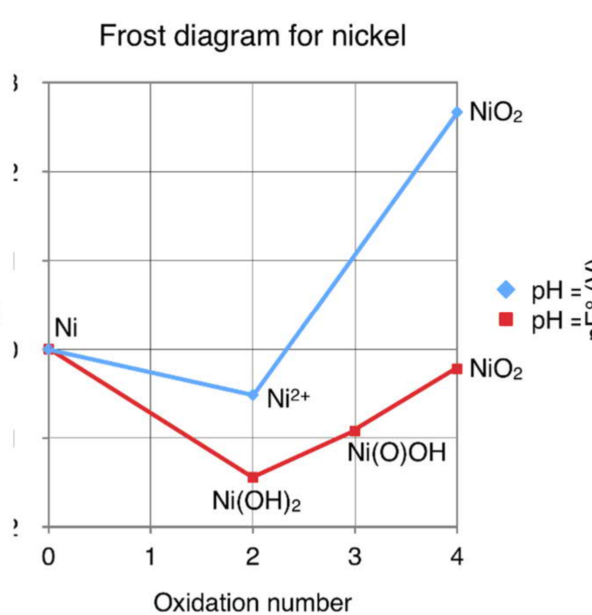
Element							
Sc			**+3**				
Ti		+2	+3	**+4**			
V		+2	+3	**+4**	**+5**		
Cr		+2	**+3**	+4	+5	+6	
Mn		**+2**	+3	+4	+5	+6	+7
Fe		**+2**	**+3**	+4	+5	+6	
Co		**+2**	**+3**	+4	+5		
Ni		**+2**	+3	+4			
Cu	+1	**+2**	+3				
Zn		**+2**					

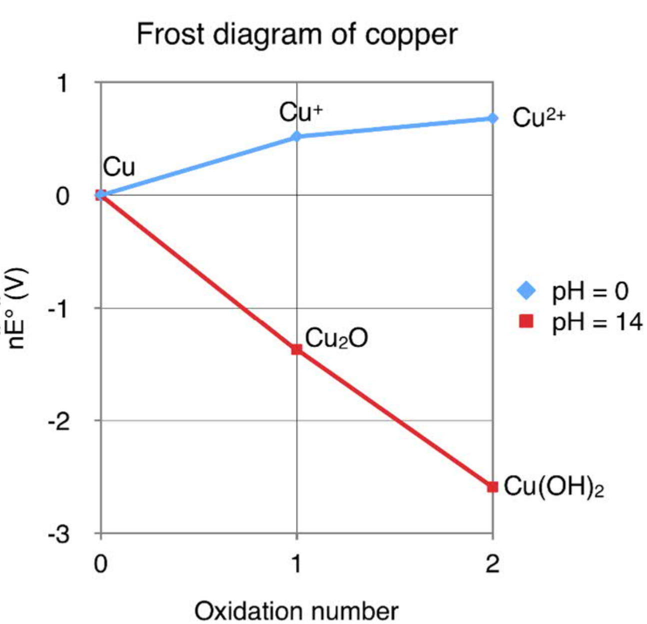
Mn, Fe, Co, Ni, Cu

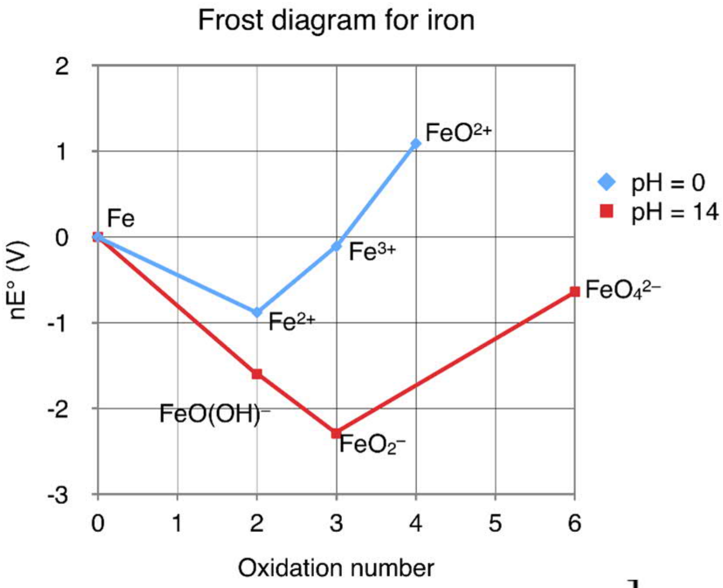

Frost diagram for manganese
nE° (V)
Oxidation number
pH = 0
pH = 14
Mn
Mn2+
Mn3+
MnO2
H3MnO4
HMnO4–
MnO4–
Mn(OH)2
Mn2O3
MnO2
MnO43–
MnO42–
MnO4–

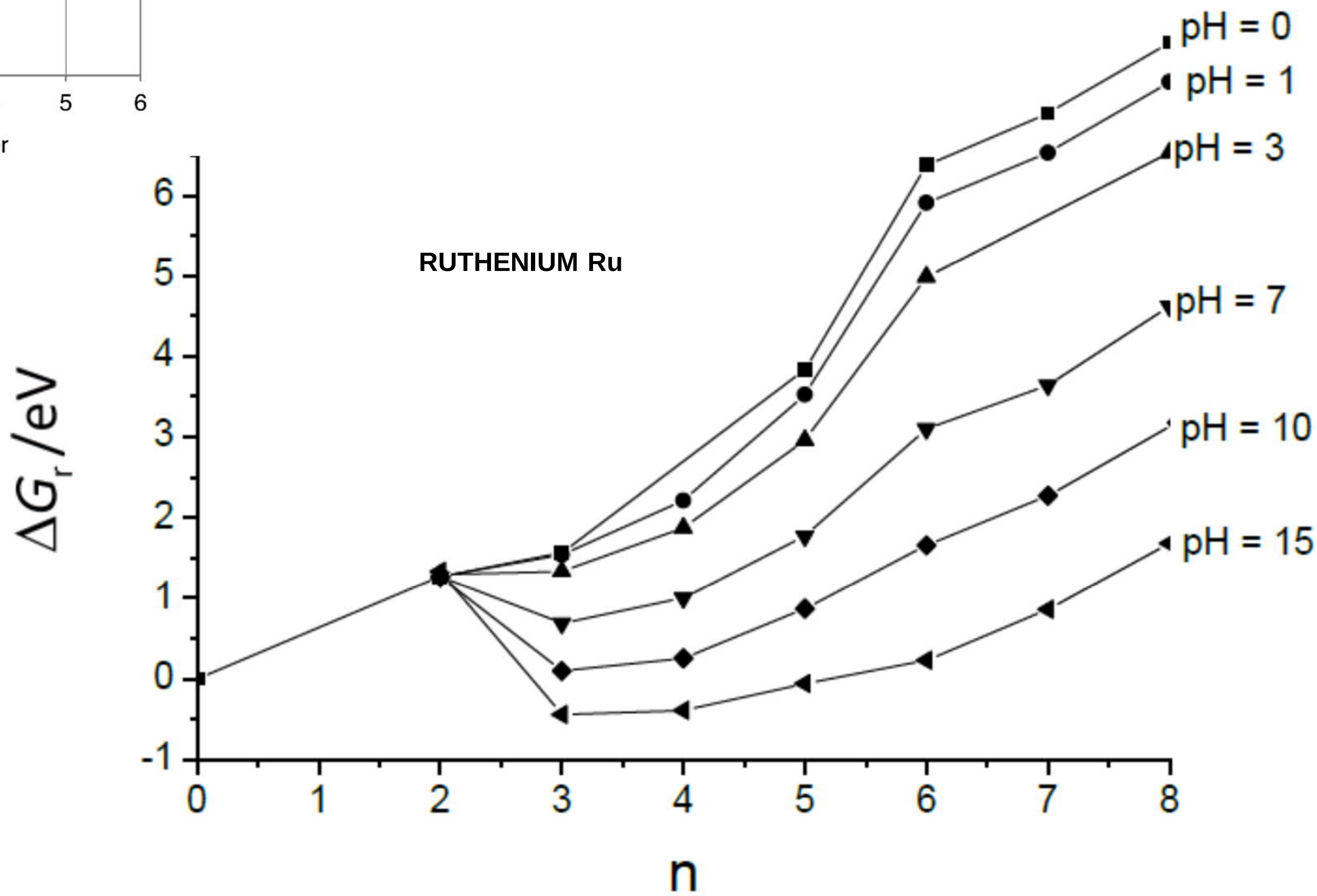

Frost diagram for iron
nE° (V)
Oxidation number
pH = 0
pH = 14
Fe
Fe2+
Fe3+
FeO2+
FeO(OH)–
FeO2–
FeO42–


Frost diagram for cobalt
nE° (V)
Oxidation number
pH = 0
pH = 14
Co
Co2+
Co3+
CoO2
Co(OH)2
Co(O)OH
CoO2


Frost diagram for nickel
Oxidation number
Ni
Ni2+
NiO2
Ni(OH)2
Ni(O)OH
NiO2

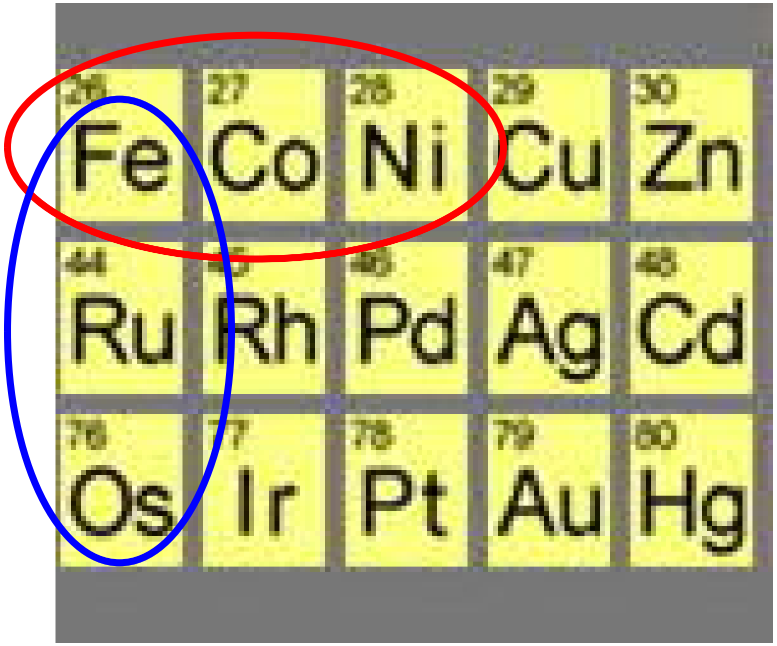

Frost diagram of copper
nE° (V)
Oxidation number
pH = 0
pH = 14
Cu
Cu+
Cu2+
Cu2O
Cu(OH)2


Frost diagram for iron
nE° (V)
Oxidation number
Fe
Fe^{2+}
Fe^{3+}
FeO^{2+}
$FeO(OH)^-$
FeO_2^-
FeO_4^{2-}
pH = 0
pH = 14
2
1
0
-1
-2
-3
0
1
2
3
4
5
6


RUTHENIUM Ru
ΔG_r /eV
n
pH = 0
pH = 1
pH = 3
pH = 7
pH = 10
pH = 15
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8

Fe, Co, Ni & Platinum Metals (Ru, Os, Rh, Ir, Pd, Pt)

- **Horizontal relationships:**
  (1) Fe, Co, Ni, (2) light Pt metals, (3) heavy Pt metals
- **Vertical relationships:**
  (1) Fe, Ru, Os, (2) Co, Rh, Ir, (3) Ni, Pd, Pt
- **Electronegativities: Fe 1.8, Co 1.9, Ni 1.9, all Pt metals 2.2**
- **Oxides:**
  - +II: (Fe,Co,Ni,Pd)O
  - +II/III: $(Fe,Co)_3O_4$
  - +III: $(Fe,Co,Rh,Ir)_2O_3$
  - +IV: $(Ru,Os,Rh,Ir,Pd,Pt)O_2$
  - +VIII: $(Ru,Os)O_4$



OCTAHEDRAL COORDINATION

- Common for Mn, Fe, Co, Ni, Cu

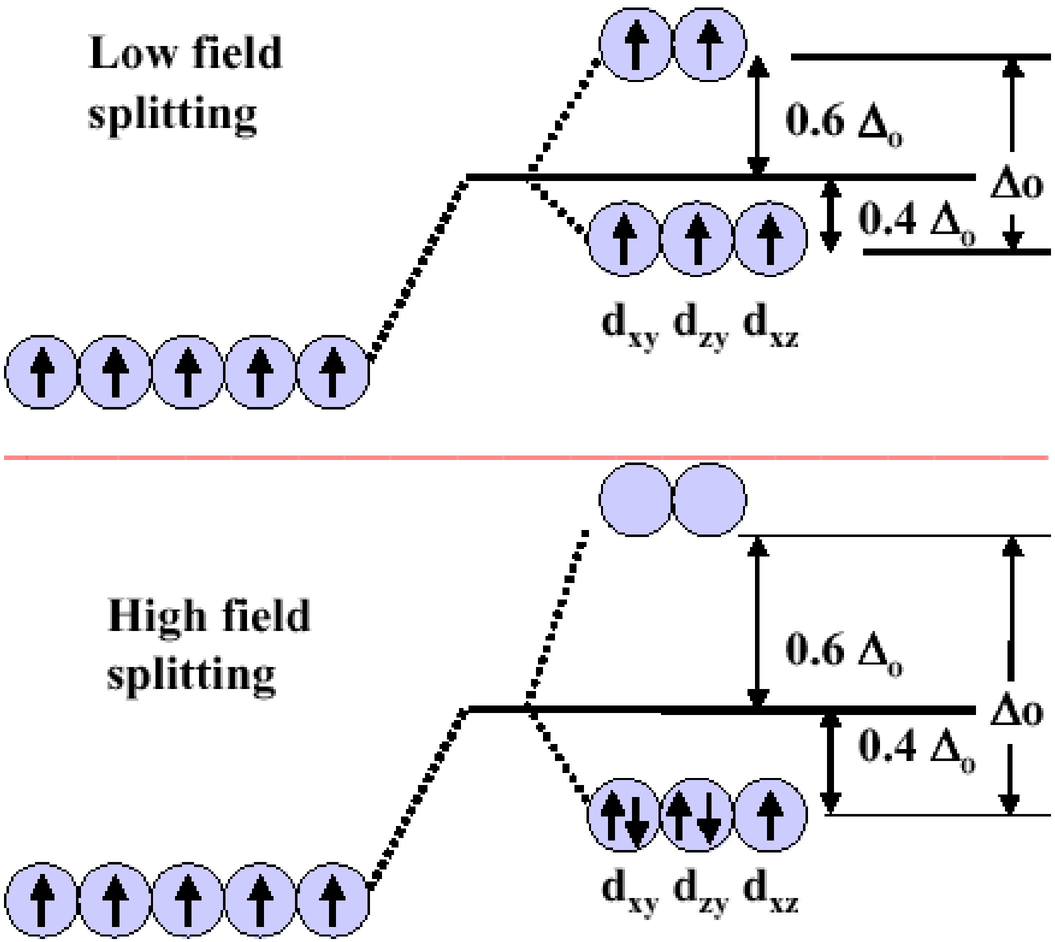
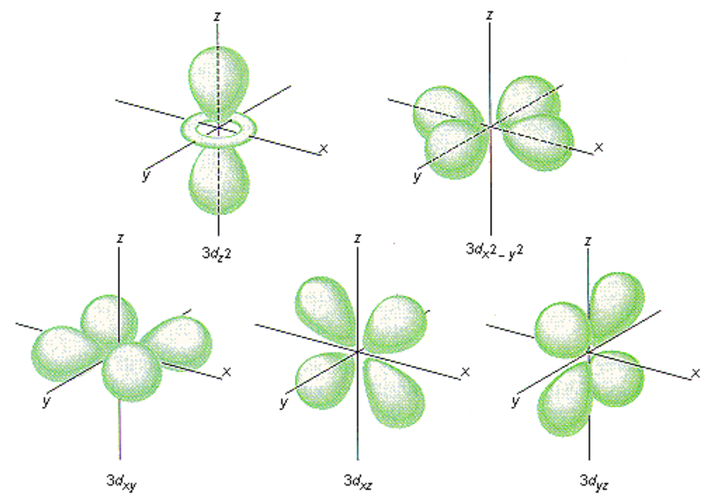


Figure 5. The two cases of crystal field splitting for the octahedral geometry.



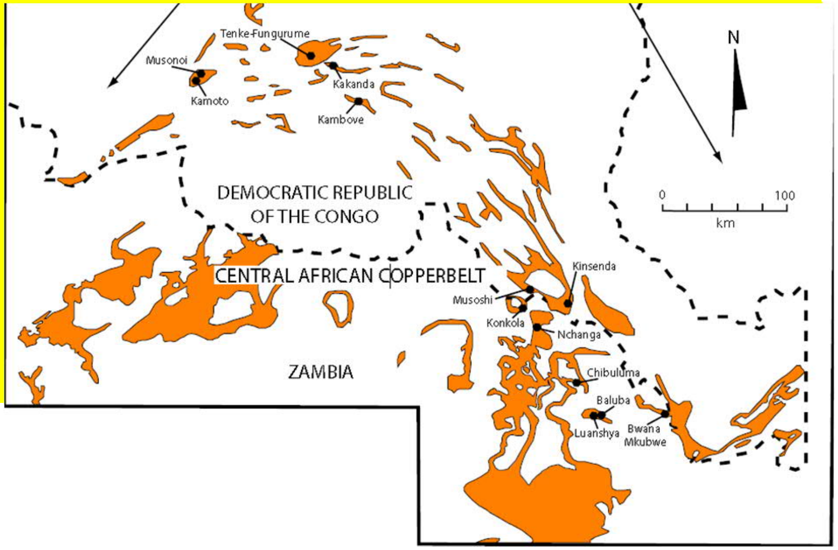
IRON COMPOUNDS

- Iron compounds mainly at the oxidation states +II and +III
- Fe(II) compounds tend to be oxidized to Fe(III) compounds in air
- Fe(II) compounds called **ferrous**, Fe(III) compounds **ferric**
- **ferrite** (magnetic spinel Fe(II/III) oxides) *versus* **ferrate** ($[FeO_4]^{4-}$, $[FeO_4]^{3-}$ & $[FeO_4]^{2-}$) !!!

  (c.f. sulphite-sulphate, **manganite-manganate**, **cuprates !!!**)
- In rare compounds Fe occurs also at higher oxidation states, e.g. K_2FeO_4
- **Fe(IV) is a common intermediate in many biochemical oxidation reactions**
- ^{57}Fe Mössbauer spectroscopy is a powerful tool to investigate oxidation states and other bonding properties of Fe in its compounds
- Many important **mixed-valence Fe(II)/Fe(III) compounds**, such as magnetite Fe_3O_4
- Main **industrial-scale** products/intermediates: $FeSO_4 \cdot 7H_2O$ and $FeCl_3$

COBALT

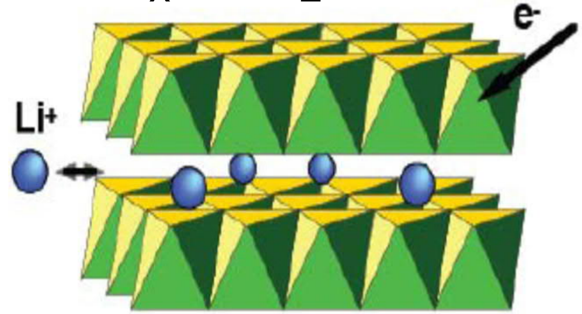
- Cobalt-based blue pigments (cobalt blue; $CoAl_2O_4$) have been used since ancient times in jewelry, paints and glass
- Ancient miners used the German name *kobold ore* (*goblin ore*) for some blue-pigment producing minerals
- In 1735 metallic cobalt was reduced from these ores (first metal discovered since ancient times) and named *kobold*
- Nowadays only minor amounts of Co are produced from Co ores, e.g. cobaltite CoAsS, the main production being as a by-product of Cu and Ni mining
- The copper belt in Africa (Congo, Zambia) is the main source of cobalt
- Co is used as a metal in magnetic, wear-resistant, high-strength alloys
- Cobalt $\rightarrow$ $LiCoO_2$!
- OXIDES:
  - CoO: green, rock-salt, AFM (T_N = 291 K)
  - Co_3O_4: blue, spinel, AFM (T_N = 40 K)
  - Co_2O_3: black

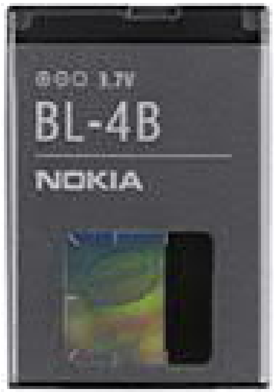


Freeport Cobalt

In Kokkola:
Outokumpu → OMG → FreeportCobalt → Umicore

Li_xCoO_2





For Chemical Applications

- Cobalt Acetate
- Cobalt Carbonate
- Cobalt Hydroxide
- Cobalt Oxide
- Cobalt Sulfate
- Coarse Grade Cobalt Powder
- Recycling

For Pigment and Ceramic Applications

Ceramic Pigments

- Cobalt Oxide

Plastic Pigments

- Cobalt Oxide
- Cobalt Hydroxide

Glass Pigments

- Cobalt Oxide

For Powder Metallurgy Applications

- S-Series Cobalt Powder
- R-Series Cobalt Powder
- Granulated Cobalt Powder
- Coarse Grade Cobalt Powder

For Battery Applications

Precursors

- Battery Grade Cobalt Oxide
- Mixed Metal Hydroxides

Battery Materials

- Fine Cobalt Powder
- Cobalt Hydroxide

Raw Materials

- Battery Grade Cobalt Powders
- Cobalt Sulfate

COPPER

- **Known since 5000 BC:**

  lat. *Cuprum* (Cyprus; oldest mining places, 3000 BC)

- **Occurrence: 68 ppm; mainly as sulphides**

- **Electronegativity: 1.9**

- **Similarities with alkali metals: $d^9s^2 \rightarrow d^{10}s^1$**

  however, Cu smaller, denser, less reactive, more electronegative, and forms coordination compounds

- **Binary oxides: Cu_2O, CuO**

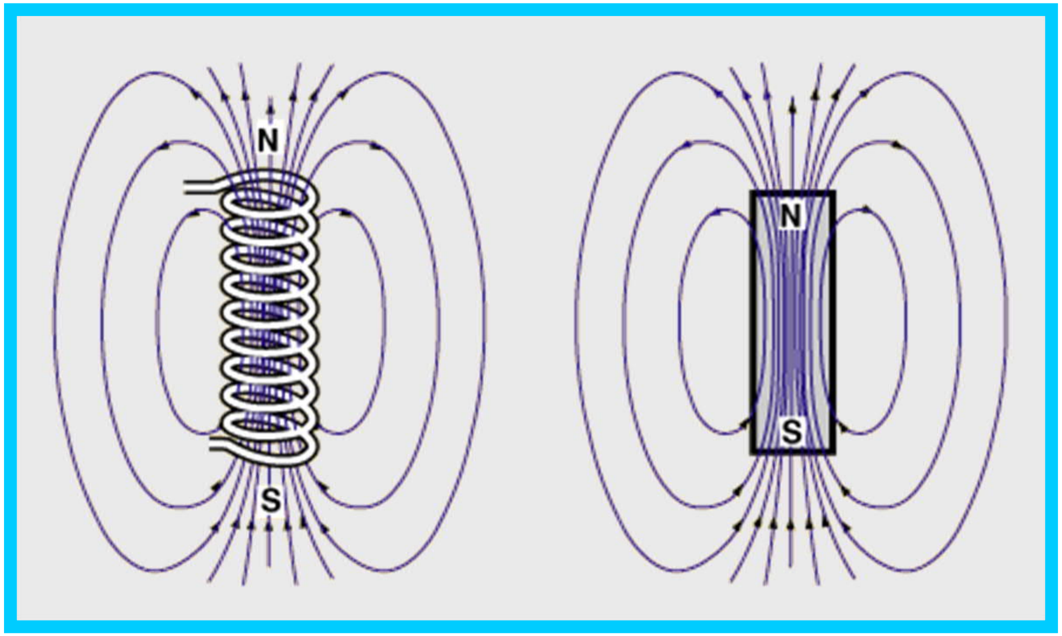
- **Compounds with higher oxidation states:**

  $LaCuO_3$, K_3CuF_6, $KCuO_2$, high-T_c superconducting oxides

- **How to stabilize the high oxidation states for transition metals:**

  - combine with the most electronegative anions
  - combine with the most electropositive cations
  - use highly oxidizing synthesis conditions/high pressures

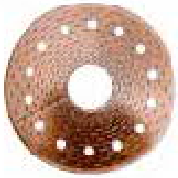
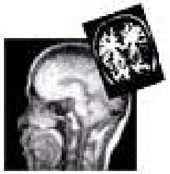
- **Enzyme reactions: Cu(I) → Cu(III)**

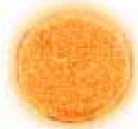
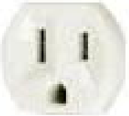
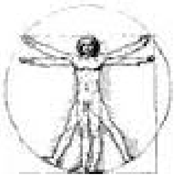


MAGNET

- **Magnet: solid/bar/coil that creates a magnetic field**
- **Electromagnet: electric current**
- **Permanent magnet: unpaired electrons**
- **Magnets have two poles: *S* (*south*) and *N* (*north*)**
- **Same-type poles repel each other and opposite-type poles attract each other**

Magnetic Field Ranges

Field Size		Example
850T		the strongest Destructive Pulsed magnet
60T		60 T long Pulse magnet
33T		33T continuous field magnet
2T		MRI machine
4×10^{-1}T		Stereo Speaker Magnets

Field Size		Example
4×10^{-1}T		lodestone Mineral magnetite
3×10^{-1}T		Household refrigerator magnet
10^{-2} T		Surface of Sun
10^{-4} T		Near Household Wiring
3×10^{-5} T		Surface of Earth
3×10^{-10}T		Produced by Human Body

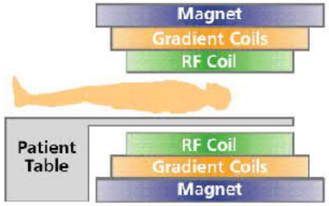
Superconducting Magnets

- Solenoid as in conventional electromagnet.
- But once current is injected, power supply turned off, current and magnetic field stays forever…

…as long as $T < T_c$

Magnets for MRI

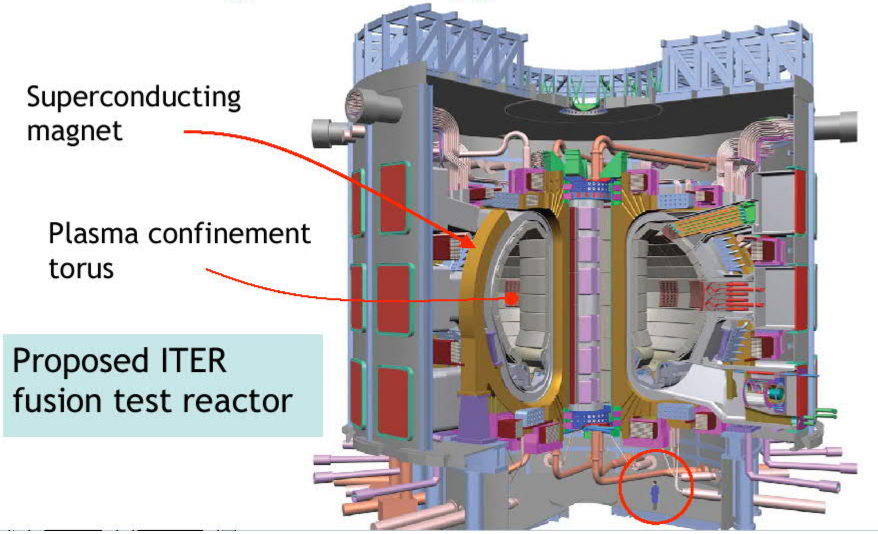
- Magnetic Resonance Imaging typically done at 1.5 T
- Superconducting magnet to provides static magnetic field
- Spatial resolution of positions of tracer atomic nuclei.



900 MHz NMR (UW Chemistry)

21.7 T field

Large scale applications



Proposed ITER fusion test reactor

MAGNETIC SUSCEPTIBILITY

Magnetization (M):
magnetic field induced in sample in external magnetic field (H)

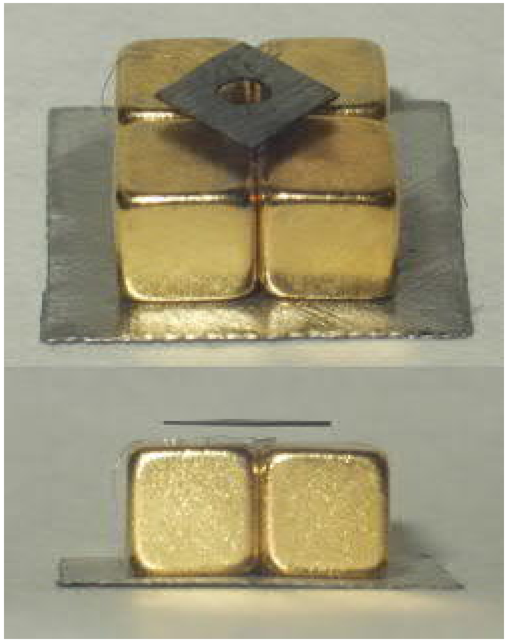
Magnetic susceptibility: $\chi = M / H$

DIAMAGNET:	$\chi < 0$	**(very small)**
PARAMAGNET:	$\chi > 0$	**(very small)**
FERROMAGNET:	$\chi > 0$	**(very large)**
ANTIFERROMAGNET:	$\chi > 0$	**(small)**
FERRIMAGNET:	$\chi > 0$	**(large)**

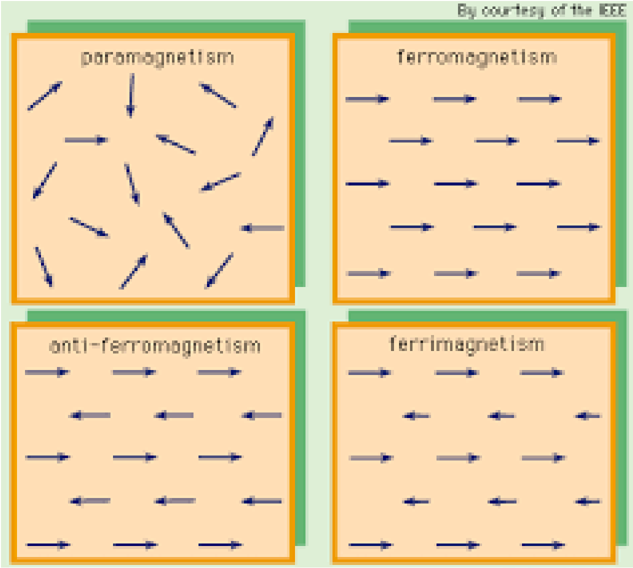
DIAMAGNETISM ("NON-MAGNETISM")

- **All materials are diamagnetic**
- **Due to the movement of all electrons in atoms**
- **Diamagnetic material repels external field ($\chi < 0$)**
- **Diamagnetism is of several orders of magnitude weaker phenomenon compared to other phenomena of magnetism**

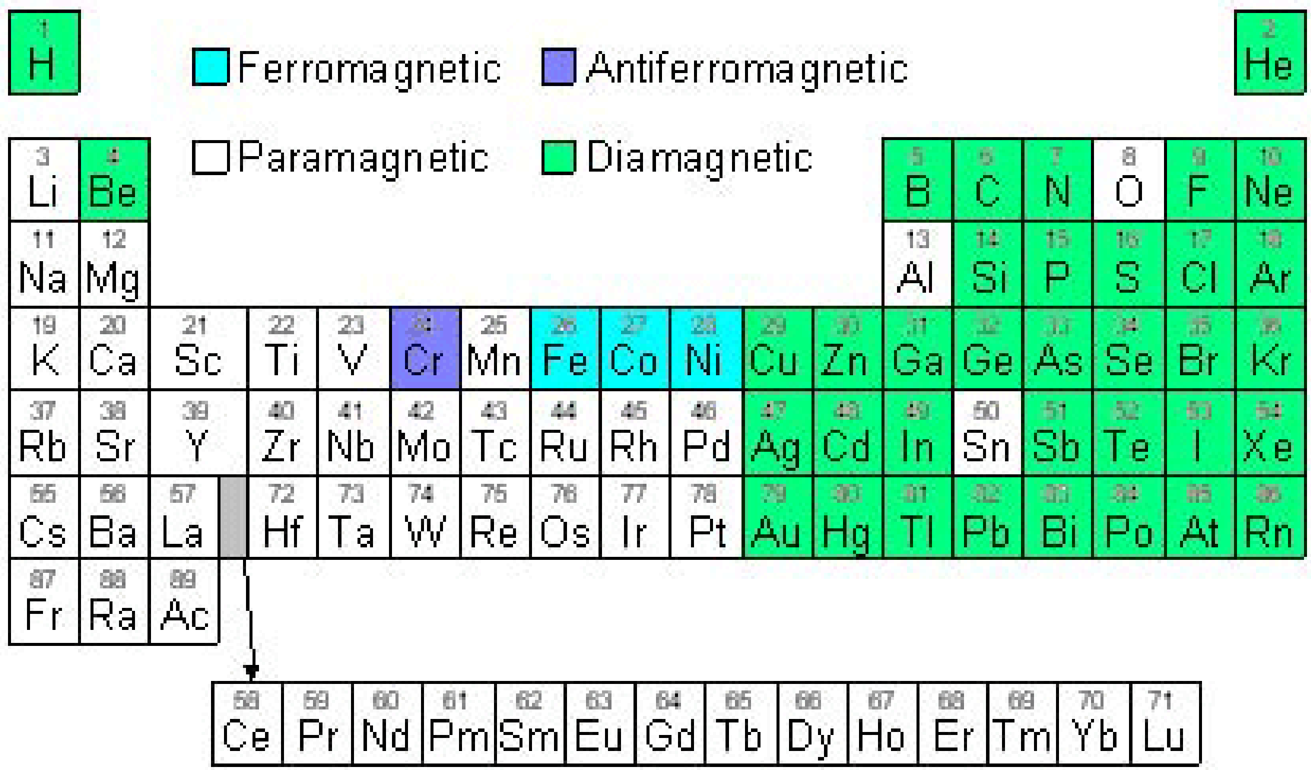
  (material is said to be diamagnetic only if it does not show other forms of magnetism)
- **e.g. water: $\chi = -9.05\times10^{-6}$**
- **So-called pyrolytic carbon is a particularly strong diamagnet (χ up to -400×10^{-6})**
- **Superconductors are perfect diamagnets (in their superconducting state): $\chi = -1$**
- **Superconductors perfectly repel external fields (Meissner effect)**



Pyrolitic carbon bar levitates above permanent magnet

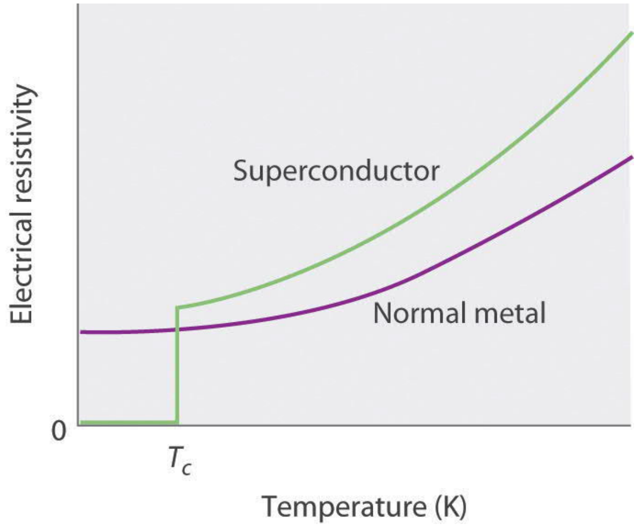


RT MAGNETISM OF PURE ELEMENTS

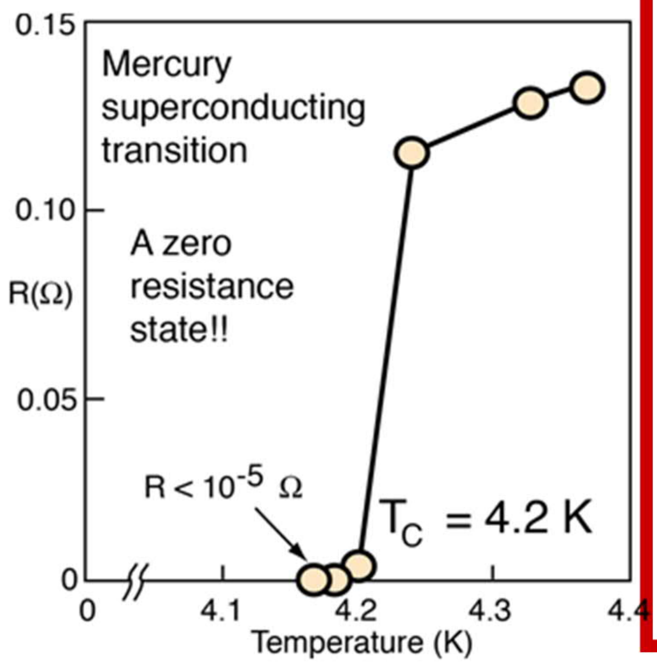


Ferromagnets: T_C [K]	
iron	1043
cobalt	1404
nickel	628
gadolinium	289
erbium	32
dysprosium	155
barium ferrite	720
strontium ferrite	720
Alnico	1160
Alumel	436
Mutamel	659
Permalloy	869
Trafoperm	1027
NdFeB	580
$SmCo_5$	990
Sm_2Co_{17}	1070
CrO_2	390
$CuAlMn_3$	???
$La_xCa_{1-x}B_6$	900
MnAs	318
MnBi	633
polymerized C_{60}	~500

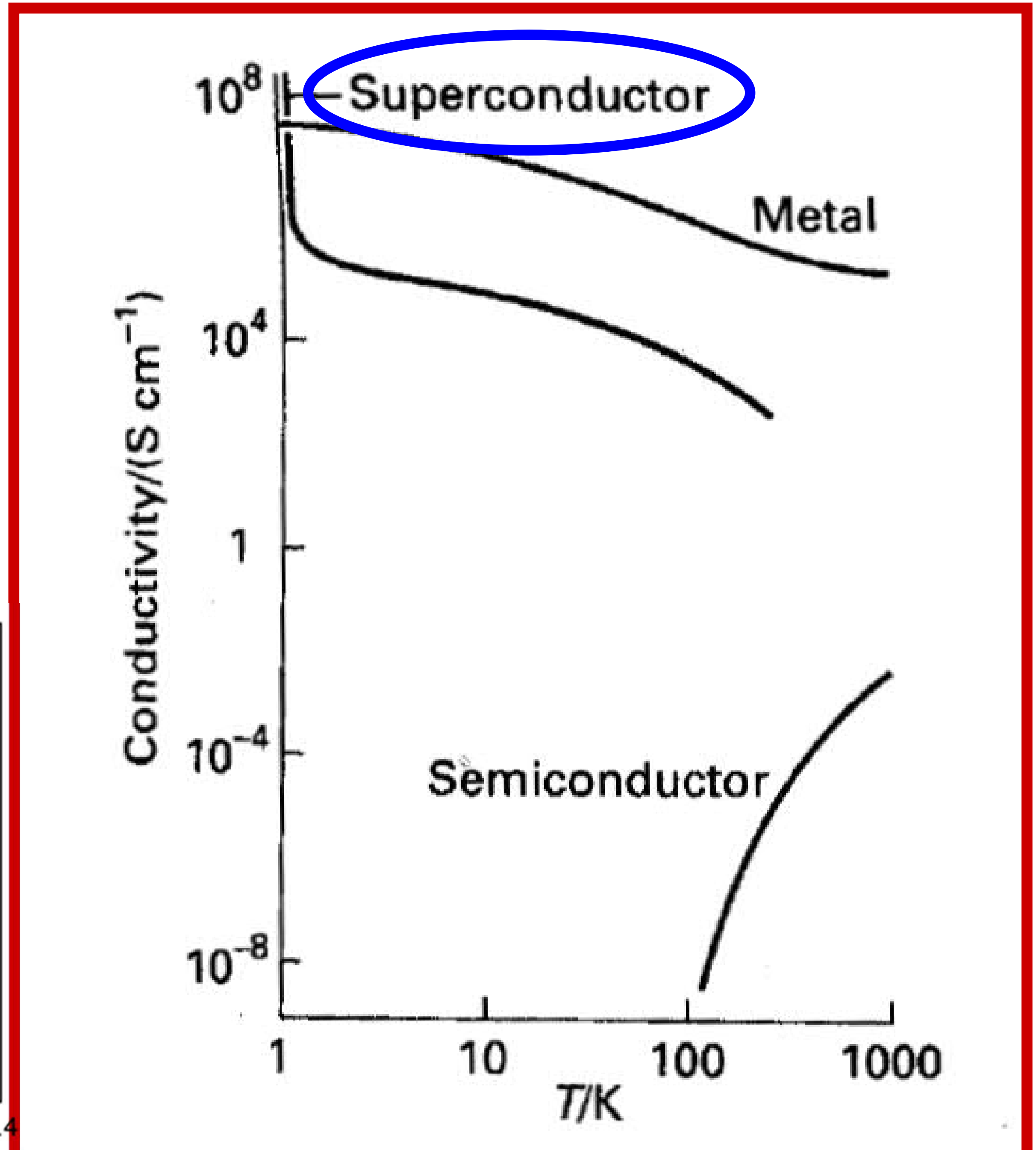
Antiferromagnets: T_N [K]	
$CoCl_2$	25
CoF_2	38
CoO	291
chromium	475
Cr_2O_3	307
erbium	80
$FeCl_2$	70
FeF_2	79 - 90
FeO	198
FeMn	490
α-Fe_2O_3	953
MnF_2	72 - 75
MnO	122
MnSe	173
MnTe	310 - 323
$NiCl_2$	50
NiF_2	78 - 83
NiFeO	180
NiO	533 - 650
$TiCl_3$	100
UCu_5	15
V_2O_3	170



Electrical resistivity
Superconductor
Normal metal
0
T_c
Temperature (K)



0.15
Mercury superconducting transition
0.10
A zero resistance state!!
R(Ω)
0.05
R < 10^-5 Ω
T_C = 4.2 K
0
0
4.1
4.2
4.3
4.4
Temperature (K)



10^8
Superconductor
Metal
10^4
Conductivity/(S cm^-1)
1
10^-4
Semiconductor
10^-8
1
10
100
1000
T/K

SUPERCONDUCTIVITY

Nobel 1913

Superconductivity

1911 Kamerlingh-Onnes: $\rho = 0$

- Hg with $Tc = 4.2$ K

”Meissner effect”

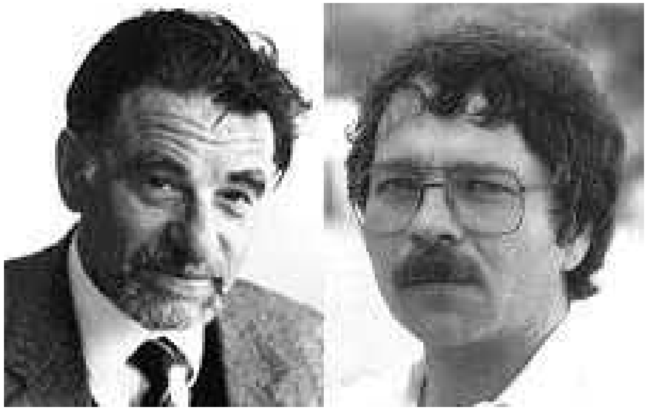
1933 Meissner and Ochenfeld:

$\chi = B/H < 0 \ \rightarrow$ levitation

High-*Tc* superconductivity

1986: Bednorz and Müller

- $(La,Ba)_2CuO_4$ with $T_c = 30 \sim 40$ K



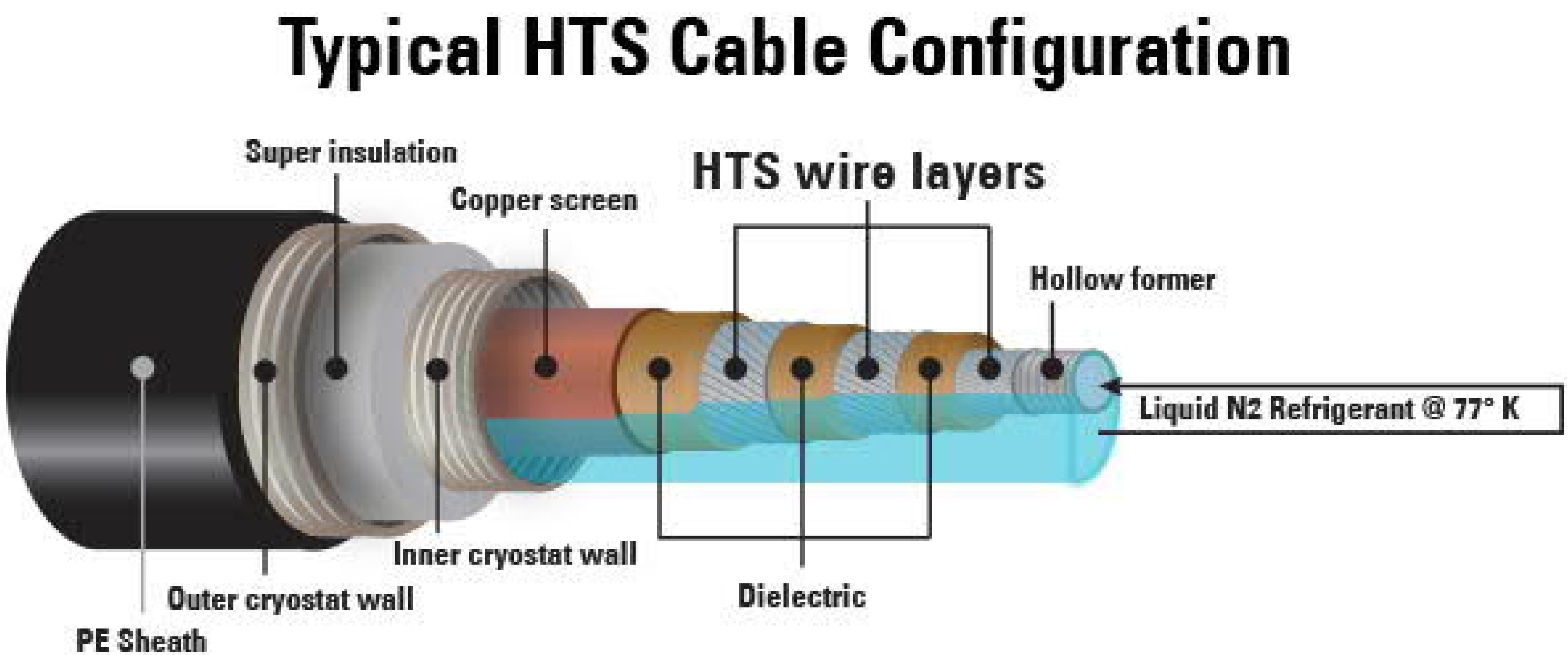
Nobel 1987

Present record in T_c:

138 K for $HgBa_2Ca_2Cu_3O_{8+\delta}$

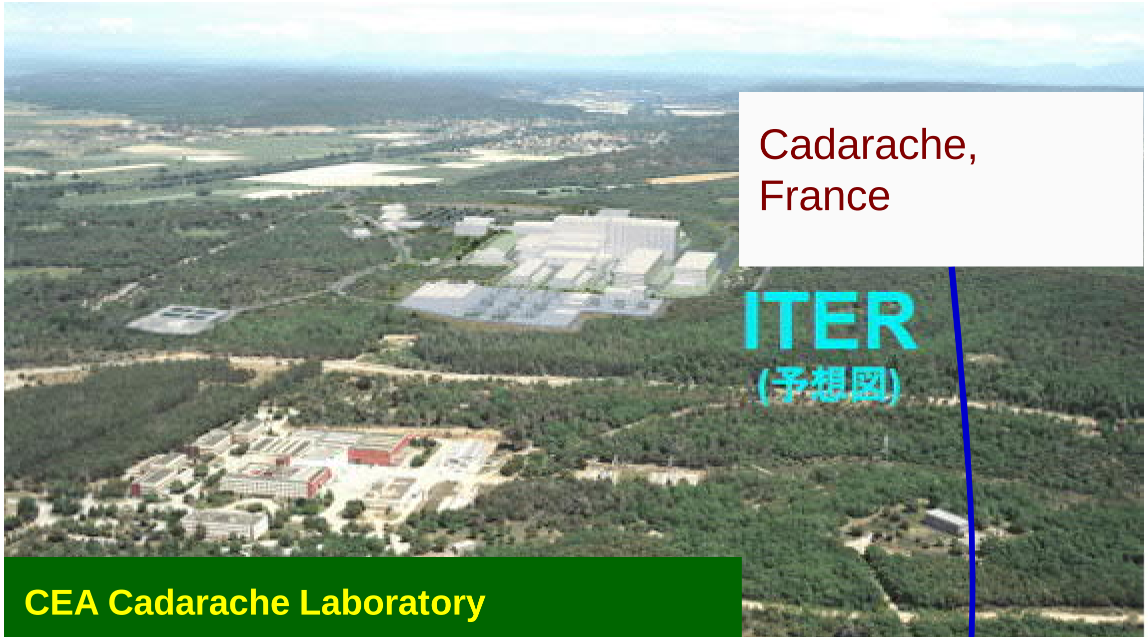
SUPERCONDUCTING POWER CABLES

- Normal Cu wires: 20% energy waste
- High-temperature superconductor cables introduced since 2000s
- In 2008 the longest cable installed in Long Island, New York: transmitting up to 574 megawatts of electricity (enough to power 300,000 homes)

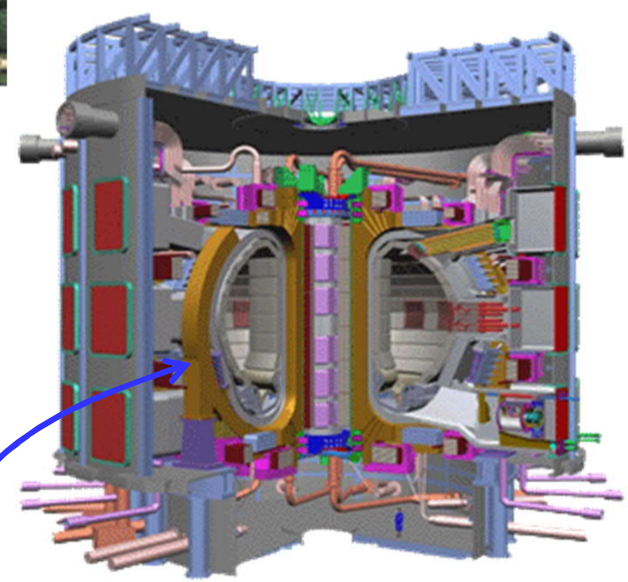


ITER: International Thermonuclear Experimental Reactor

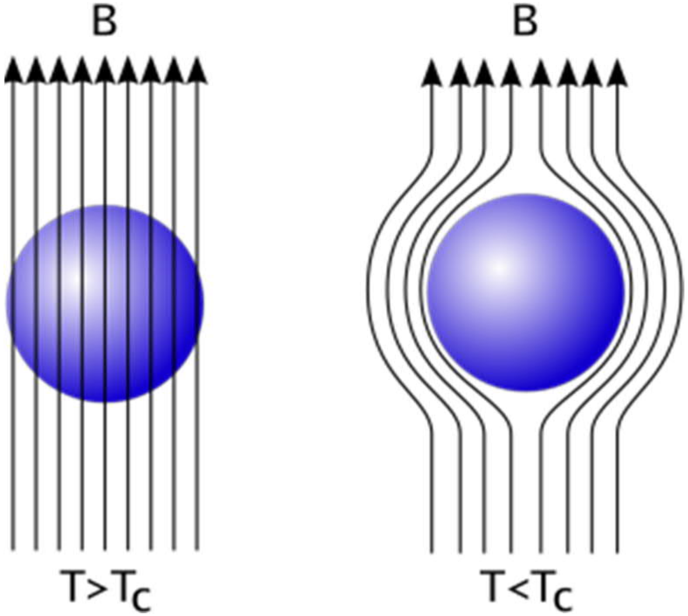
since October, 2007

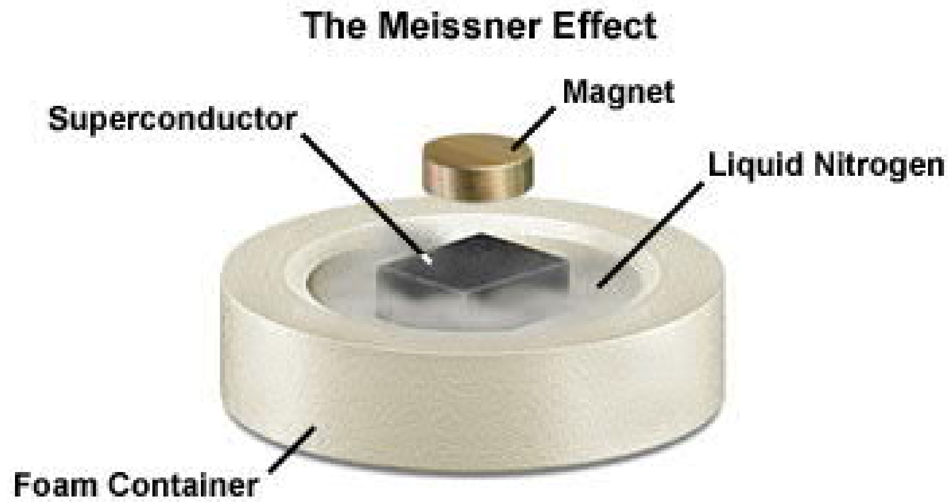


Nuclear Fusion Reactor



Superconducting Magnets

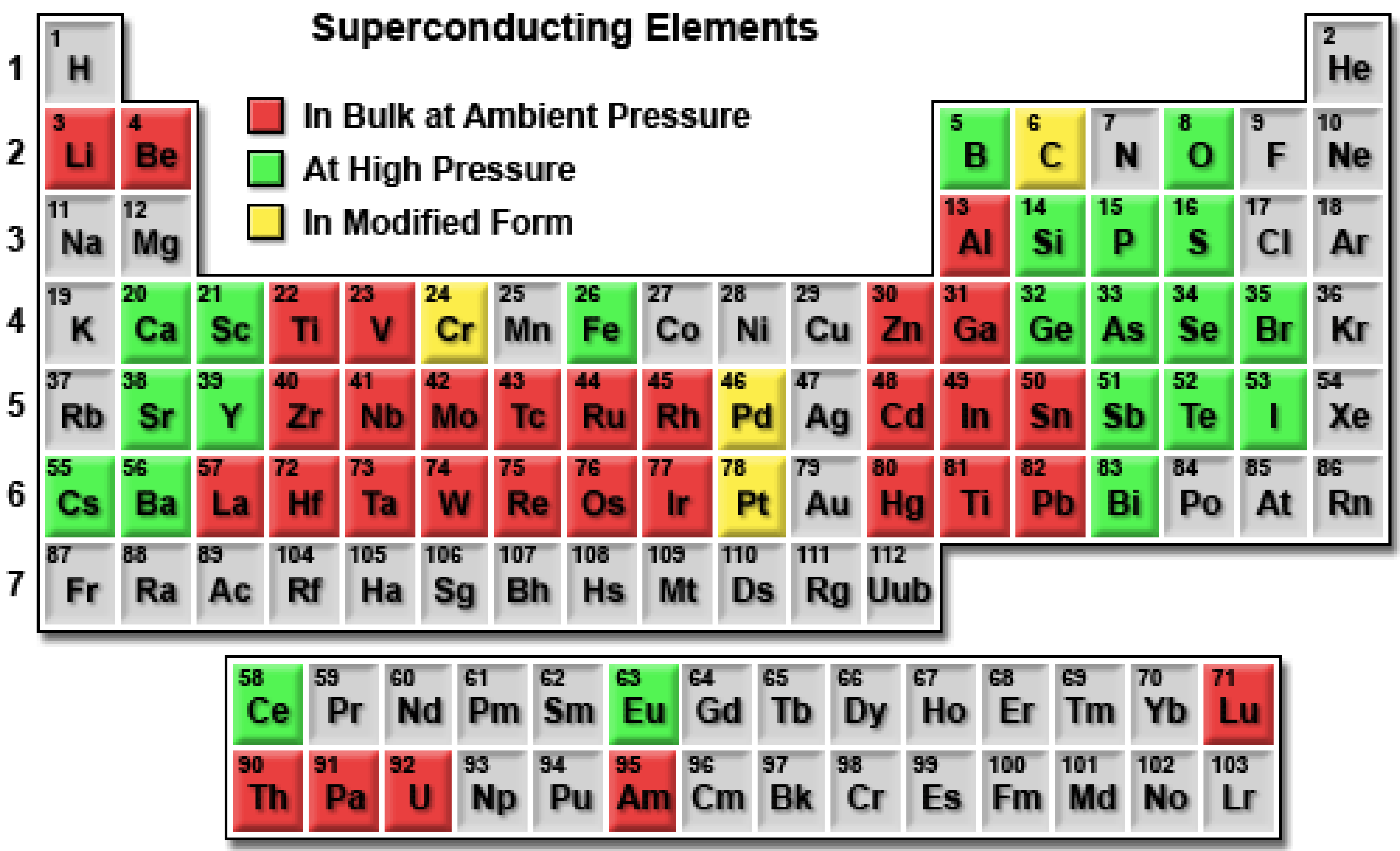

B
B
T>T_C
T<T_C

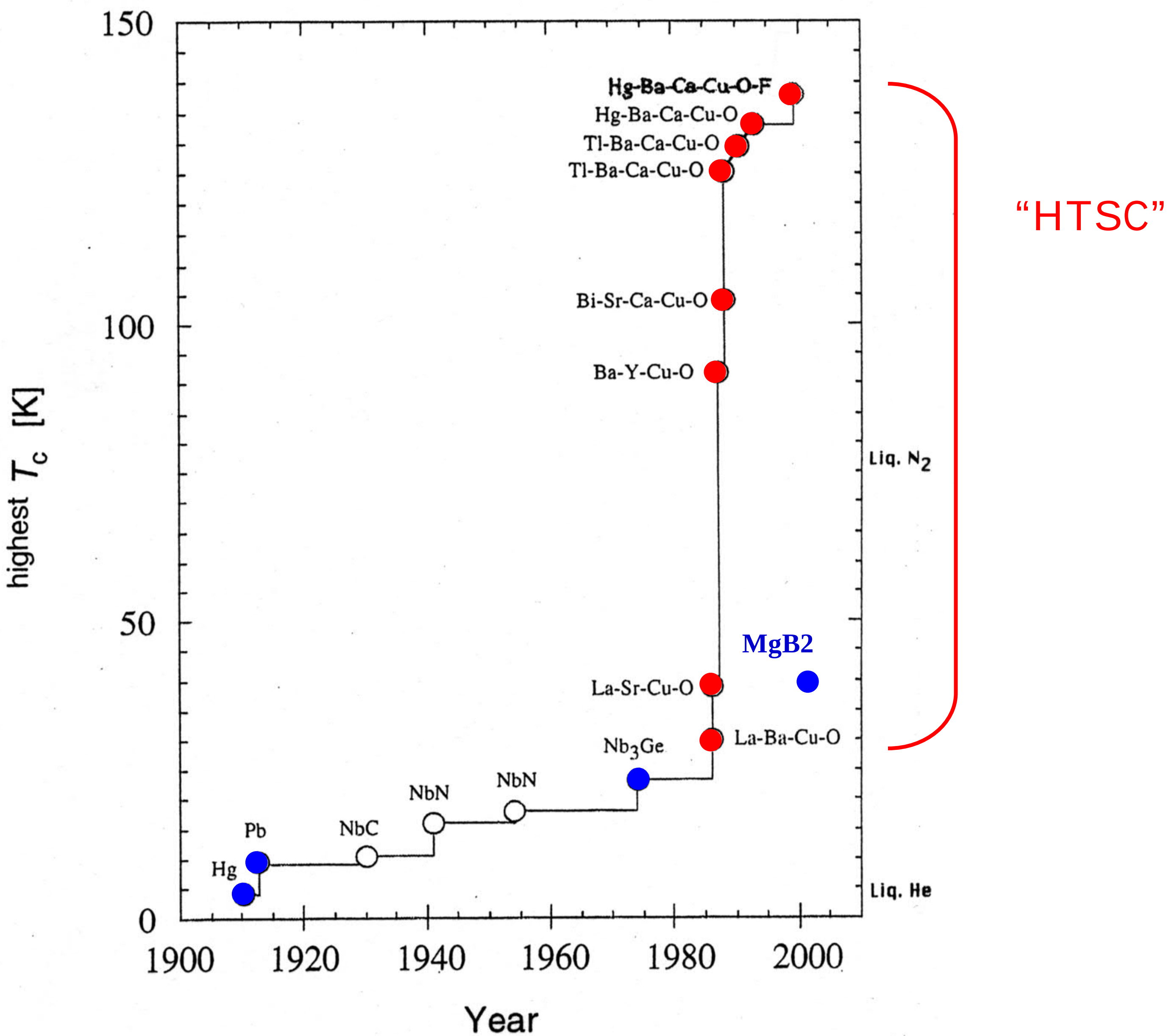

The Meissner Effect
Magnet
Superconductor
Liquid Nitrogen
Foam Container


登録商標
天賞
宮城優良清酒

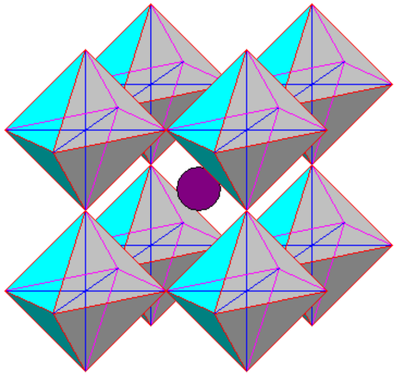
Super-Maglev Train

- **603 km / hour**
- **Test line 42.8 km**

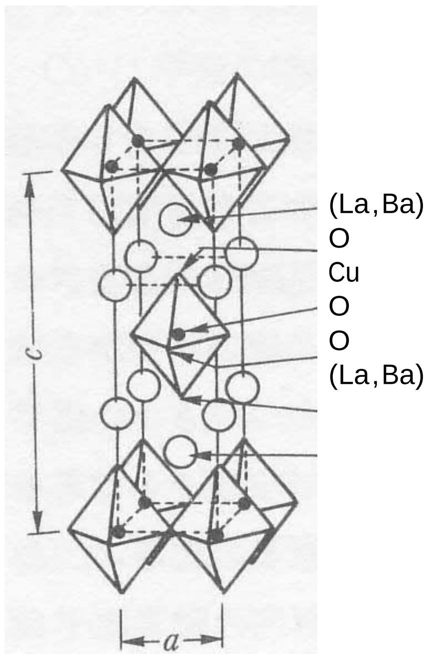

Superconducting Elements
In Bulk at Ambient Pressure
At High Pressure
In Modified Form
1 2 3 4 5 6 7
1 H
2 He
3 Li 4 Be
5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg
13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 57 La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Ti 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 89 Ac 104 Rf 105 Ha 106 Sg 107 Bh 108 Hs 109 Mt 110 Ds 111 Rg 112 Uub
58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cr 99 Es 100 Fm 101 Md 102 No 103 Lr

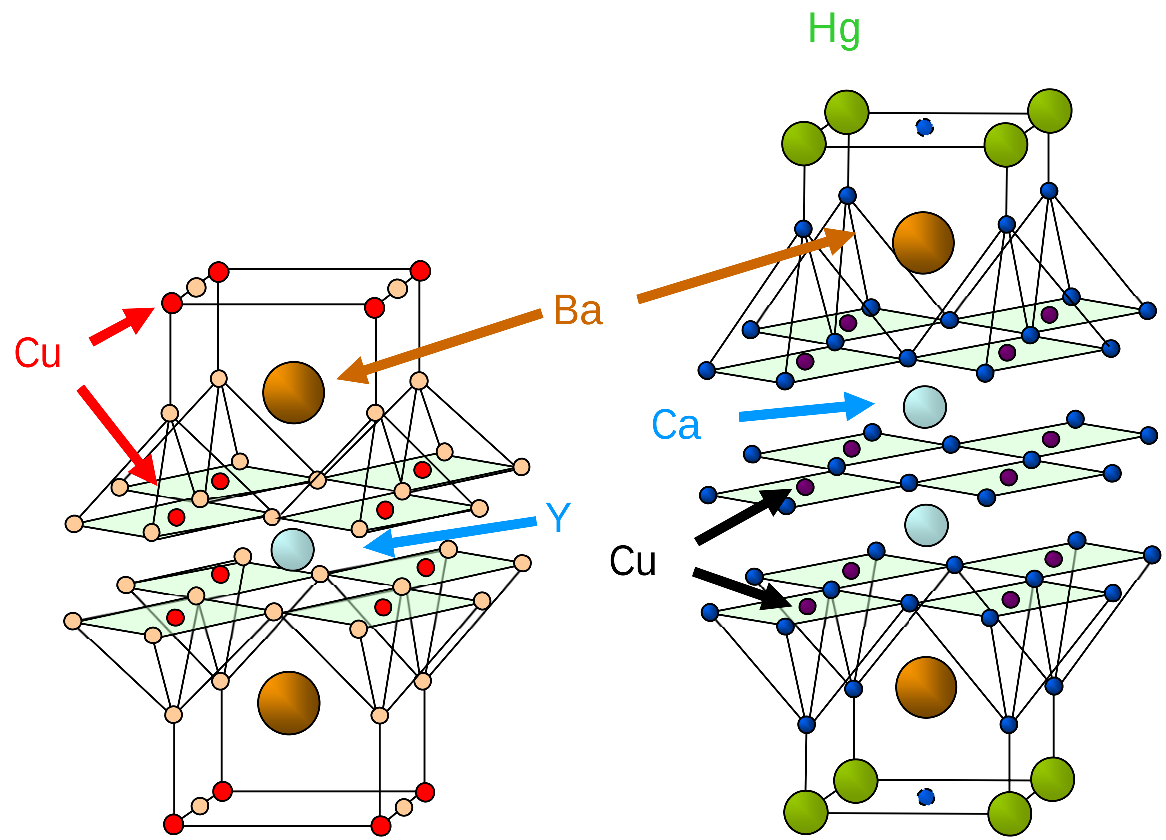

150
100
50
0
highest T_c [K]
1900
1920
1940
1960
1980
2000
Year
Hg
Pb
NbC
NbN
NbN
Nb_3Ge
La-Ba-Cu-O
La-Sr-Cu-O
Ba-Y-Cu-O
Bi-Sr-Ca-Cu-O
Tl-Ba-Ca-Cu-O
Tl-Ba-Ca-Cu-O
Hg-Ba-Ca-Cu-O
Hg-Ba-Ca-Cu-O-F
MgB2
Liq. N_2
Liq. He
"HTSC"

Crystal Structures of
High-*Tc* Superconductive Copper Oxides



Perovskite $CaTiO_3$





$(La,Ba)_2CuO_{4+\delta}$

$T_c \approx 35$ K

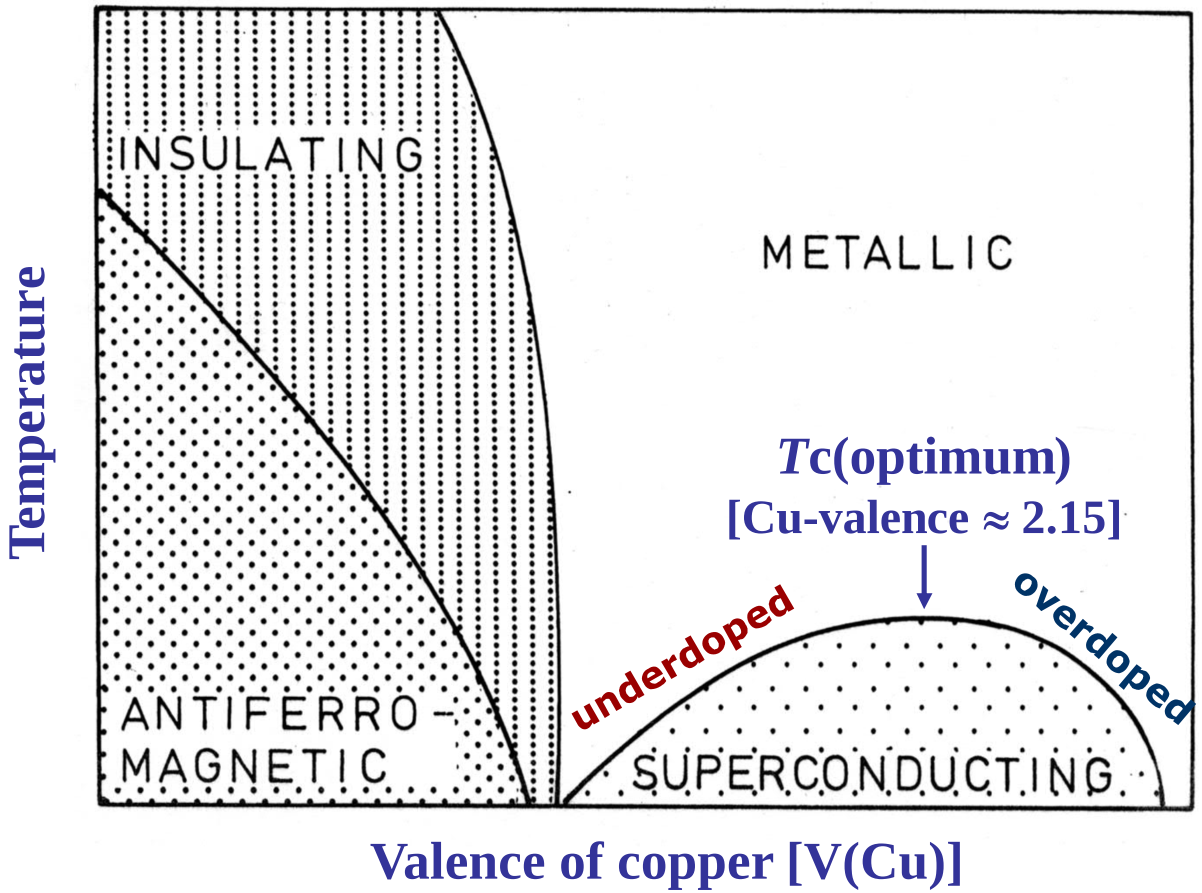
$YBa_2Cu_3O_{7-\delta}$

$T_c \approx 92$ K

$HgBa_2Ca_2Cu_3O_{9-\delta}$

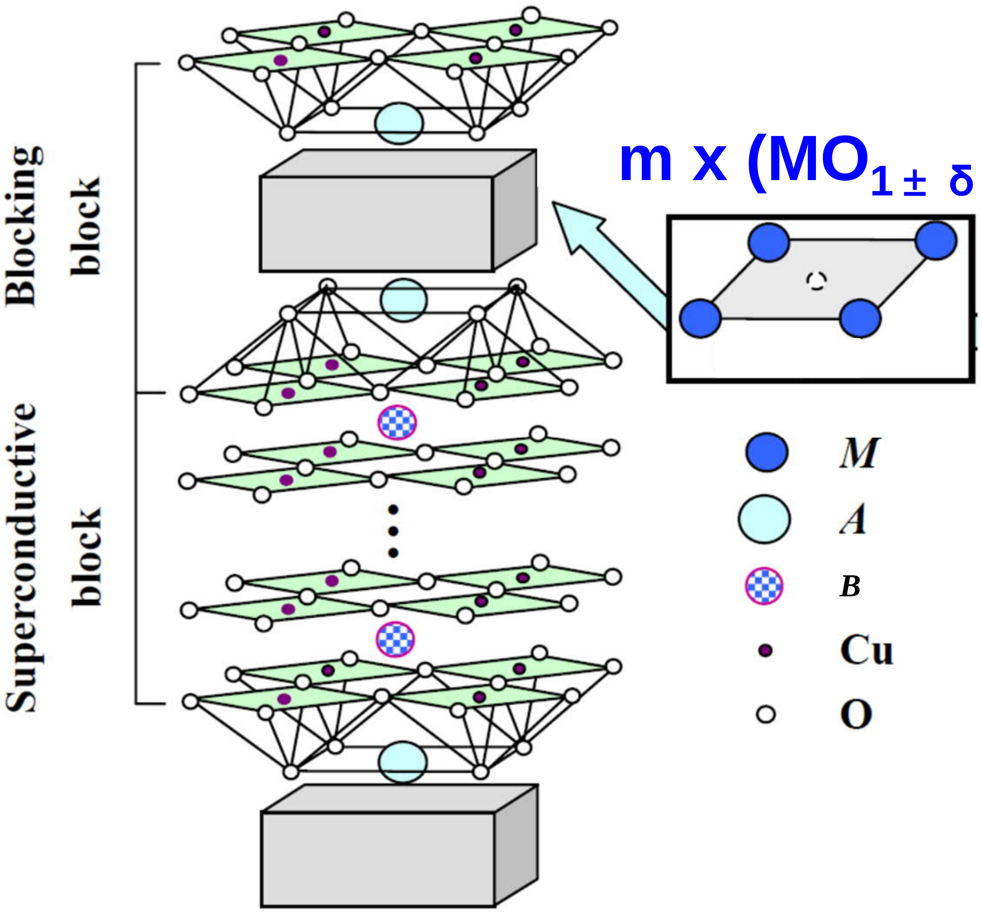
$T_c \approx 135$ K

Phase Diagram of HTSC

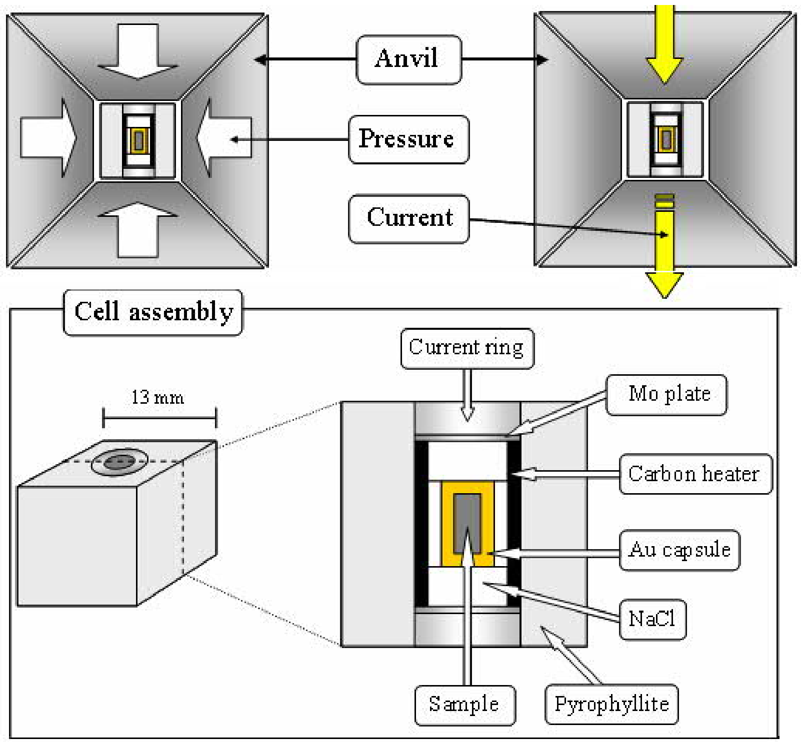


GENERAL FORMULA

- $M_mA_2B_{n-1}Cu_nO_{m+2+2n\pm\delta}$
- M-m2(n-1)n
- HOMOLOGOUS SERIES: M, m, A and B fixed, n varies



M. Karppinen & H. Yamauchi,
Control of the charge inhomogeneity and high-*Tc* superconducting properties in homologous series of multi-layered copper oxides, *Mater. Sci. Eng. R* **26**, 51-96 (1999).



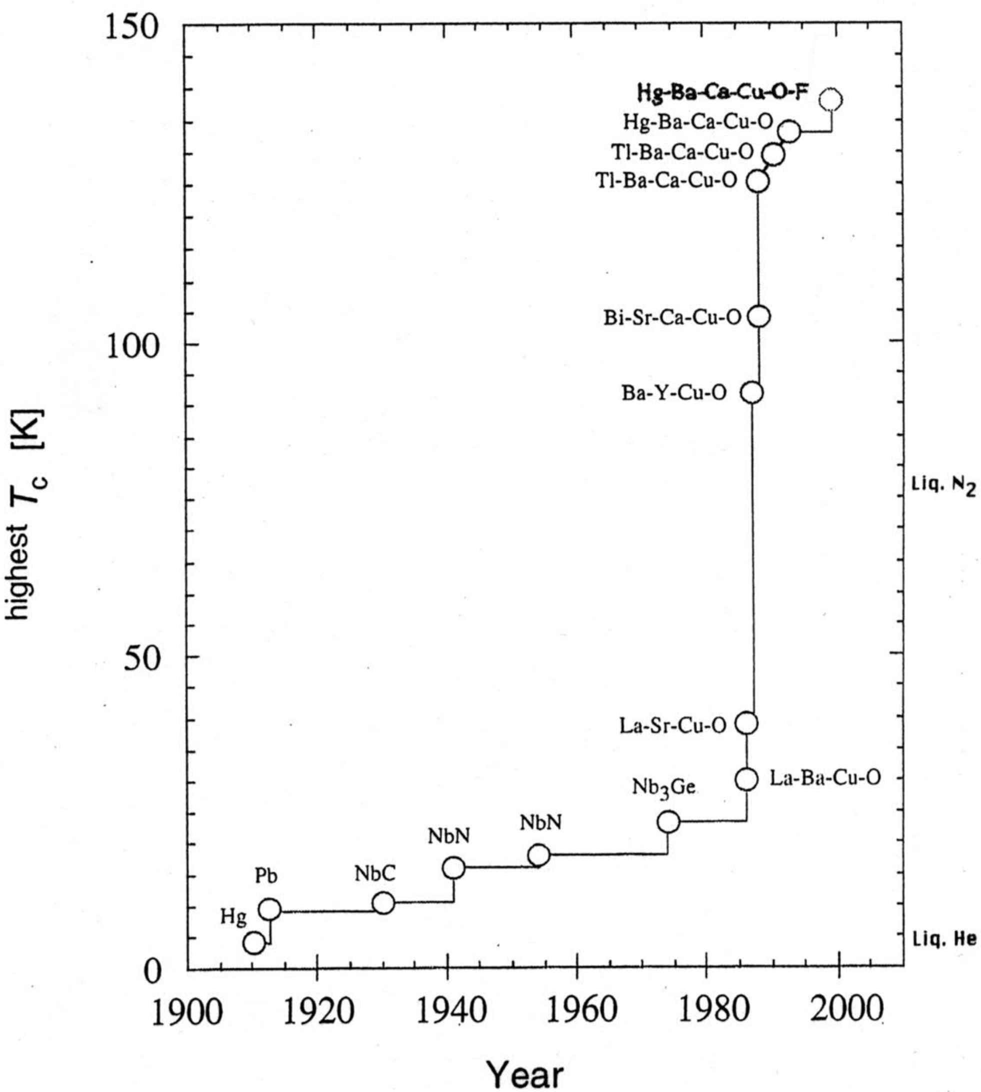
HIGH-PRESSURE SYNTHESIS

- 5 GPa = 50 000 atm
- 400 – 1200 ^{o}C
- 10 – 120 min
- 50 – 100 mg

HP equipment
at Tokyo Tech

H. Yamauchi & M. Karppinen, *Supercond. Sci. Technol*. 13, R33 (2000).

Search for new high-T_c superconductors



$(La_{0.92}Ba_{0.08})CuO_4$

$(La_{0.92}Sr_{0.08})_2CuO_4$

$YBa_2Cu_3O_7$

$Bi_2Sr_2Ca_2Cu_3O_{10}$

$Tl_2Ba_2Ca_2Cu_3O_{10}$

$TlBa_2Ca_2Cu_3O_9$

$HgBa_2Ca_2Cu_3O_9$

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIA or 0
Period 1	1 H																	2 He
Period 2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
Period 3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
Period 4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
Period 5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
Period 6	55 Cs	56 Ba	57 to 71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Ti	82 Pb	83 Bi	84 Po	85 At	86 Rn
Period 7	87 Fr	88 Ra	89 to 103	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt									

Lanthanide series →	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinide series →	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

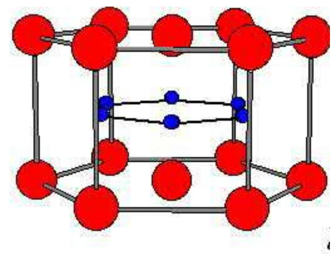
$$M_mA_2Q_{n-1}Cu_nO_{m+2+2n+\delta}$$

M - m2(n - 1)n

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 to 71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Ti	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 to 103	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt									

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Akimitsu 2001:
MgB_2



Hosono 2001:
[La(O,F)][FeAs]