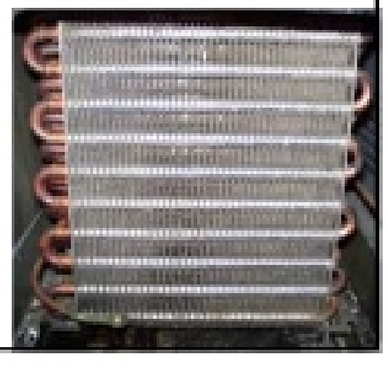
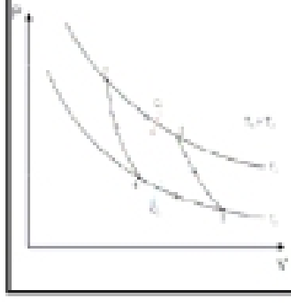
Avicenna
(c. 980 – 1037)

- Persian polymath; the foremost physician and philosopher of his time. He was also an astronomer, chemist, geologist, logician, paleontologist, mathematician, physicist, poet, psychologist, soldier, statesman, and teacher.
- He invented the refrigeration coil, which condenses aromatic vapors.
- This was a breakthrough in distillation technology and he made use of it in his steam distillation process to separate temperature sensitive material and produce essential oils.



Nicolas Léonard Sadi Carnot
(1796 – 1832)



- Proposed Carnot Engine in 1824 on which Carnot Cycle was modeled
- From Carnot Cycle came the concept of Heat Pump which follows Carnot Engine working in reverse (Carnot Cycle anti-clockwise)
- Later in 1852 Lord Kelvin built the first Heat Pump

Development of the Kelvin Absolute Temperature Scale

- William Thomson (later Lord Kelvin) was interested in Charles's Law which states that when a gas is cooled by one degree Celsius, it's volume drops by 1/273
  - This would lead to zero volume at -273°C
  - How can matter exist without taking up space?
- Thomson instead suggested that it was the energy of motion that decreased with temperature
  - At -273°C, the molecules cease motion and essentially not take up space
  - He called -273°C absolute zero because no further temperature reduction is possible. This later became known as 0 Kelvin.

Lord Kelvin

Sources: University of Glasgow and World of Scientific Discovery

Liquefaction of Oxygen

Liquid oxygen is the liquid form of element oxygen. In nowadays it is widely used in many fields.

Liquefaction of substance that normally exists as gas dates back to the 18th century. The first successful attempt was made by a French mathematician Gaspard Monge, who liquefied sulfur dioxide in 1784. In the following decades, people succeeded in liquefy many gases, but none of them was able to liquefy oxygen gas. In the late 1840s, Irish physical chemist Thomas Andrews suggested that every gas has a precise temperature, which is the critical temperature. Above the temperature gas cannot be liquefied even under great pressure. Following Andrews idea, scientist came up with the idea of using 'cascade' process to get low temperature. In this method, one liquefied gas is used to cool another gas with lower critical temperature, and so on. By using the cascade process, French physicist Louis Paul Cailletet liquefied three gases, oxygen, nitrogen and carbon monoxide.

Now liquid oxygen is playing a significant role in both industry and research. Compare with oxygen gas, liquid oxygen is much easier to store and transport. Liquid oxygen is stored in hospitals for patients with breathing problems. It is also used as oxidizer in industry, such as producing ion and many other metals. Furthermore, liquid oxygen is used as oxidizer in spacecraft such as rockets. Without liquefaction of oxygen, one cannot provide enough oxygen with such limited space and cannot put rocket into use.

Liquefaction of oxygen is an important event in the history. It was one of the human first attempts to liquify 'permanent gas'. Liquid oxygen also serves as an important substance today.

Dewar, Sir James
(1842 – 1923)

- Scottish chemist and physicist; best known for his work with low-temperature phenomena.
- He studied the specific heat of hydrogen and was the first person to produce hydrogen in liquid form (1898) and to solidify it (1899).
- He constructed a machine for producing liquid oxygen in large quantities in 1891 and subsequently invented the Dewar flask or thermos in 1892.
- The Dewar flask is a container for storing hot or cold substances. It consists of two flasks (usually glass), one inside the other, separated by a vacuum that reduces the transfer of heat, preventing a temperature change.

Sir James Dewar
(1842–1923)
Invented Vacuum flask in 1892

$$\eta = \langle v \rangle \langle l \rangle \rho = \frac{1}{n\sigma}\sqrt{\frac{8kT}{\pi m}}\, nm = Const\sqrt{T}$$

Why vacuum? L ~ size

James Dewar

Invented a silvered, double walled, glass vacuum vessel to contain cryogenic liquids for the first time, for relatively long periods, before they evaporated.

Most widely known in connection with his work on the liquefaction of the so-called permanent gases and his researches at temperatures approaching absolute zero.

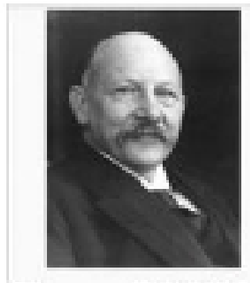
His work was used to help create vapor-cooled radiation shields and multilayer insulations

Received Hodgkins Gold Medal for his work on liquid oxygen and liquid hydrogen

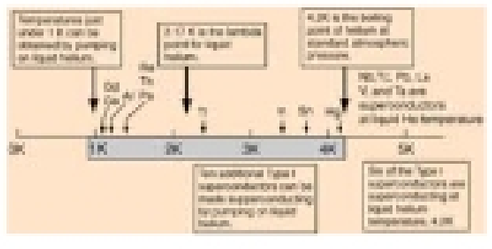
1842-1923

Important events in the history of civilization, related to cryogenics

(1908) Heike Kamerlingh Onnes liquefies helium



- Commonly used cryogenic refrigerant in physics experiments and applications
- It has very interesting properties like superfluidity
- Led to the discovery of superconductivity



- It cools down lossless superconducting magnets used in modern technological applications

The Discovery of Superconductivity

-Discovered 1911

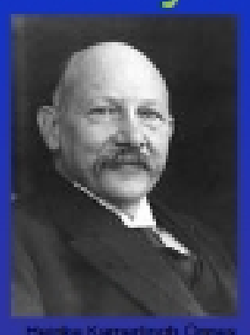
-Won Onnes Nobel in 1913

-First superconducting Materials:

1. Mercury (Gold deemed too hard to refine) (4.2K)
2. Lead (7 K)
3. Niobium Nitride (16 K)

-Made possible by liquefaction of Helium and Dewar containers

-Used to prove Tesla's Patent of low temperature reconating circuit



Heinke Kamerlingh Onnes

Heike Kamerlingh Onnes

the first person to liquify helium

21 September 1853 – 21 February 1926

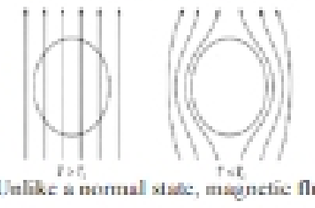
From 1871 to 1873,He studied under Robert Bunsen and Gustav Kirchhoff at the University of Heidelberg

In 1908, Heike Kamerlingh Onnes successfully liquified helium by using the Joule-Thomson effect. He lowered the temperature to less than one degree above absolute zero. At that time this was the coldest temperature achieved on earth.

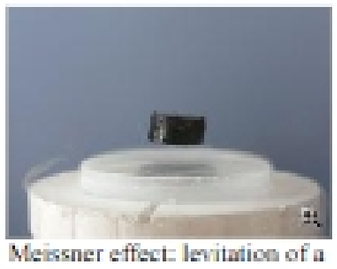
Heike Kamerlingh Onnes

Superconductivity was discovered in 1911.

- H. K. Onnes was studying the resistance of mercury using the recently-discovered liquid helium as a refrigerant.
- when mercury was cooled down to 4.2 K, he observed that the resistance abruptly disappeared.
- Superconductors show a property of perfect diamagnetism, which is called the Meissner Effect.



Unlike a normal state, magnetic flux can't penetrate a superconducting state.



Meissner effect: levitation of a magnet above a superconductor

Discovery of Superconductivity and Its Applications

- 1908, Kamerlingh Onnes first liquefied helium-4, which led to his discovery of type I superconductivity (not possible for applications because of low T_c and H_c) in 1911.
- 1961, discovery of type II superconductor with higher T_c and H_c, making applications possible.
- 1986, discovery of ceramic high temperature superconductors (HTS) with T_c above the liquid nitrogen boiling point.
- Current applications: superconducting magnets used in MRI and NMR machines, particle accelerators; SQUIDs; magnetic levitation; HTS wires, etc.
- Possible future applications: high performance transformers, power storage devices, electric power transmission, electric motors, etc.

Discovery of Superconductivity

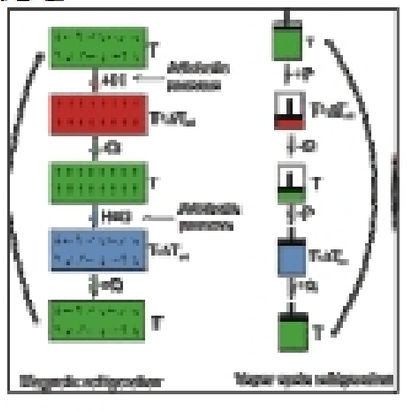
- Heike Kamerlingh Onnes
- Made possible by the recent discovery of liquid helium as a refrigerant
- First discovered super conductive material: Mercury

1933: Temperature of .25K Reached

•Several groups were able to cool past .3K with magnetic cooling.

•The technique uses adiabatic demagnetization. First suggested by Debye (1926) and Giauque (1927).

•The process is in use today both in industry, where it has been adapted to work at room temperature, and in research, where substances can be cooled to micro Kelvin.

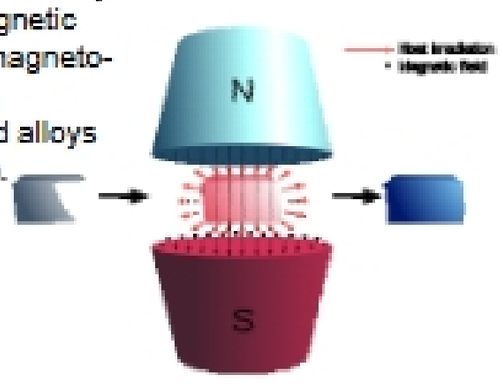


http://en.wikipedia.org/wiki/Magnetic_refrigeration

Magnetic Refrigeration

W. F. Giauque and D. P. MacDougall, 1933

Temperature change in material caused by changing magnetic field via the magneto-caloric effect. Giauque used alloys of gadolinium.

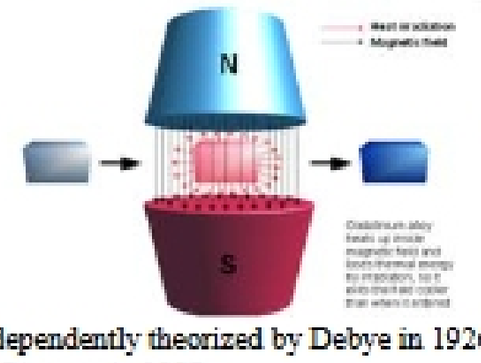


1949 Nobel Prize in Chemistry

Magnetic Cooling

Peter Debye

William Francis Giauque



- Independently theorized by Debye in 1926 and Giauque in 1927
- Adibatic demagnetization first demonstrated by Giauque in 1933
- Allowed for temperatures below 1K to be reached for the first time

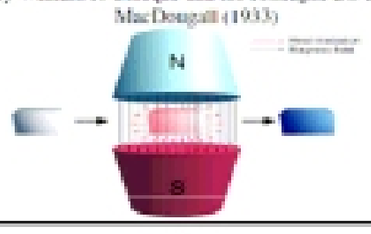
By Ishmal Lewis

Magnetic refrigeration

- discovered in pure iron in by Emil Warburg (1881)
- adiabatic demagnetization Debye (1926) and Giauque (1927)

William Francis Giauque 1895- 1982

- Magnetic cooling used to reach temperatures below 1K by William F. Giauque and his colleague Dr. D.P. MacDougall (1933)



Tupolev Tu-155

Russian Tupolev created the first commercial passenger jet that is partially fueled with liquid hydrogen. After only a few flights, the plane was changed to instead run on cooled liquid natural gas. The frequency with which we fly about in a Tupolev perhaps hints as to the level of success of this plane.