B.Sc. Phy
Part-I Paper-II
Gr-B.

Describe the different methods for Production of Low temperature.

Production of Low Temperatures:

Today research & development in physics calls for the production of very low temperatures at which new phenomena like superconductivity appearence. Method are now at hand to create temperature as low as between 10^{-2} and 10^{-6} K. The methods generally used are the following:

i) Freezing Mixture: When common salt is mixed ice, the temperature of the mixture falls below 0°c. The reason is that as soon as the salt is mixed, some of the ice melts in cooling the salt to 0°c and a saturated solution is formed. Now ice cannot remain in equilibrium with the solution at 0°c because the freezing point of solution (-22°c) is lower than the temperature of ice (0°c). Therefore, more ice in contact with the solution melts, taking the necessary latent heat from the solution which therefore cools. More salt is now dissolved to keep the solution saturated. The process is continued until the solution is cooled to -22°c when the ice is in equilibrium with the saturated solution. A mixture of ice and calcium chloride cools to -55°c and that of ice and caustic potash to -65°c.

ii) Evaporation of Liquids under Reduced Pressure

Evaporation of liquids is followed by cooling. If the evaporation is promoted by reducing the pressure on the liquid surface, the cooling is intensified. A common example of this method is the rapid evaporation of liquid-methyl chloride, liquid-ammonia and liquid-carbon-dioxide in ice plants and refrigerators. Pictet obtained a temperature of −169°C by a cascade process utilising a number of liquids of successively lower boiling points.

Very low temperatures can be obtained by the evaporation of liquid-hydrogen and liquid-helium under greatly reduced pressures. Kammerlingh Onnes, in 1921, attained a temperature of 0.82 K by evaporating liquid-helium under a pressure of 0.013 mm of mercury. Kesson, in 1932, using special diffusion pumps, reduced the pressure on the surface of liquid-helium down to 0.0036 mm of mercury and obtained a temperature of 0.726K.

iii) Adiabatic Expansion of Gases :-

When a highly compressed gas is suddenly expanded to atmospheric pressure, it does external work against the pressure of the atmosphere (and also some internal work against the molecular attractions). This work is drawn from the internal energy of the gas itself. The temperature of the gas therefore falls.

Cailletet and Pictet independently liquefied oxygen while Olszewski liquefied hydrogen by this method. Simon could liquefy even helium by subjecting it to adiabatic expansion.

iv) **Joule-Kelvin Expansion coupled with Regenrating Cooling:**

When a compressed gas, initially below its temperature of inversion, is forced through a fine orifice, its temperature falls. The fall in temperature increases as the initial temp. of the gas is decreased. Therefore, the cooled gas emerging from the orifice is made to flow back over the tube containing the incoming gas. The incoming gas is thus cooled and on expanding through the orifice becomes still more cooled. As this process is continued, the gas emerging from the orifice is progressively cooled. Ultimately, a temperature is reached at which the gas is liquefied. The process has been used in the liquefaction of a number of gases including hydrogen and helium which were liquefied at $-253°C$ and $-268°C$ respectively under one atmospheric pressure.

v) **Adiabatic Desorption:**

This process was used by Simon to produce cooling. Charcol absorbs gases with the liberation of heat. When it is desorbed i.e. when the absorbed gases are pumped off under adiabatic condition, it cools. Simon liquefied hydrogen and helium by this process.

vi) <u>Adiabatic Demagnetisation</u>:

The lowest temperatures are obtained by the method of adiabatic demagnetisation. When a paramagnetic substance is magnetised, its molecules are set in the direction of the magnetising field. The necessary work done in this process is added to the internal energy of the substance which therefore suffers a rise in temperature. If the substance is allowed to cool and then demagnetized under adiabatic conditions, the molecules return to their original random distribution and there is a corresponding fall in temperature. This effect is very much pronounced at very low temperatures.

Giauque and Mc Dougall used gadolinium sulphate (a paramagnetic salt) and a magnetic field of 8000 Gauss and obtained a temperature of 0.25 K. De-Hass and Wiersma using a mixture of chrome-potassium alum and aluminium-potassium alum went down to 0.0044 K. In 1956, Klerk, Steenland and Gorter used powdered mixed crystals of chromium-alum and aluminium-alum and attained a temp of 0.0014 K.

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