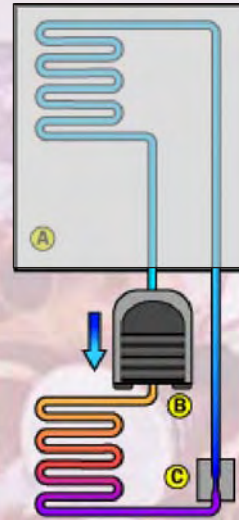


# Cryogenics - the technology of cooling

## Refrigerators

Refrigerators produce cooling by circulating a refrigerant. In a domestic refrigerator, circulating Freon liquid vapourises and cools the contents. The Freon gas is then compressed, releasing heat in an external heat exchanger. Work is done circulating and compressing the Freon. The net effect is the transfer of heat energy from the cold contents to the hotter room.

- (A) Inside the refrigerator
- (B) Compressor
- (C) Expansion valve

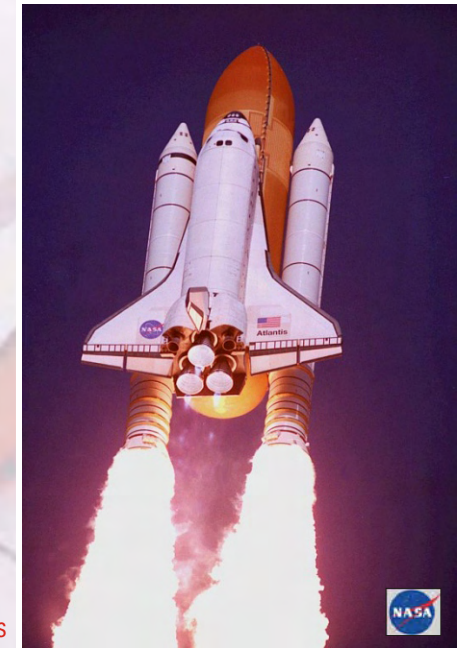


## Cryogenic liquids

### Space Shuttle

The three main engines of the Space Shuttle burn hydrogen and oxygen from vast external fuel tanks. These contain 1,500,000 litres of **liquid hydrogen** and 550,000 litres of **liquid oxygen**, taking up less volume than gas. They have a maximum thrust of  $6.9 \times 10^6$  N and fire for 8 minutes, helping to take the shuttle into orbit.

Space Shuttle Atlantis



## Dilution refrigerators

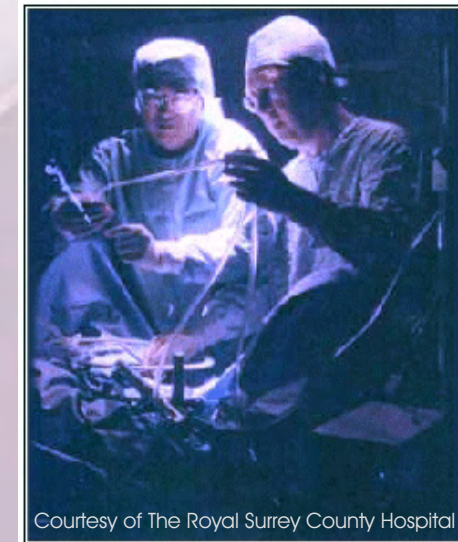
A **dilution refrigerator** circulates  $^3\text{He}$ , in a mixture of the helium isotopes  $^3\text{He}$  and  $^4\text{He}$ , to reach very low temperatures down to below  $2 \times 10^{-3}$  K (2 mK).



An Oxford Instruments  $^3\text{He}$ - $^4\text{He}$  dilution refrigerator, and a fish-eye view of it in use at Royal Holloway, University of London



**Cryosurgery** is the use of extreme cold to treat cancer. For external tumours, **liquid nitrogen** (at  $-196^\circ\text{C}$  or 77 K) is applied directly to the skin. For internal tumours, **liquid nitrogen** is circulated through a cryoprobe, which freezes and destroys the cancer cells. This procedure offers the advantage of very quick patient recovery time.



Courtesy of The Royal Surrey County Hospital

## First law of thermodynamics

Internal energy increase = work done + heat energy supplied.

## Second law of thermodynamics

Work is required to transfer heat energy from cold to hot.