Temperature

- Temperature scale was originally defined by how much mercury expands between the freezing and boiling points of water, defined as 0°C an 100°C.

$$T_C = C_1 \frac{\Delta V}{V_0} + C_2$$

Traditional thermometers work by monitoring volume changes

- Inbetween 0°C and 100°C a thermometer based on mercury and one based on Alcohol gave slightly different answers.

Ideal gas thermometers: work by measuring how pressure changes (at constant volume)

- For low densities, it was found that the ratio of pressures $P_{steam} / P_{freezing}$ at constant volume was the same (nearly) independent of the gas type. It thus gave a universal (gas independent) scale

(Psteam = Pressure at boiling point of water)

★ $$T = T_{ref} \frac{P}{P_{ref}}$$ (const volume)

So we need to pick a reference temperature, measure gas pressure at very low density (so $P_{ref} \to 0$), then, keeping the volume of gas fixed, measure the press. at some other point. This defines the temperature using ★

- In practice, the reference temperature was when the temperature when water, ice and water vapor are in equilibrium, the triple point.

  T_{ref} was chosen to be 273.16 °K to agree with the Celsius scale and Celsius' definition of degree as a unit between freezing and boiling

- All other thermometers, were then calibrated against the ideal gas one. For instance, one could measure the resistance of platinum, this resistance varies with temperature, and thus knowing the resistance determines the temperature, Platinum Resistance Thermometry (PRT)

- Slides

  (1) How to measure pressure at constant volume

  (2) The triple point of water

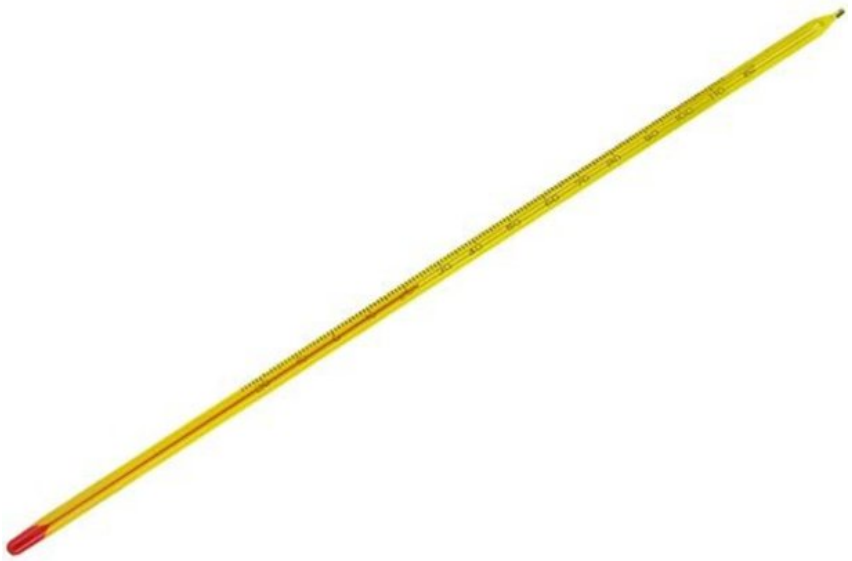
  (3) Measuring the temperature of Steam

  (4) A Platinum resitance thermometer.

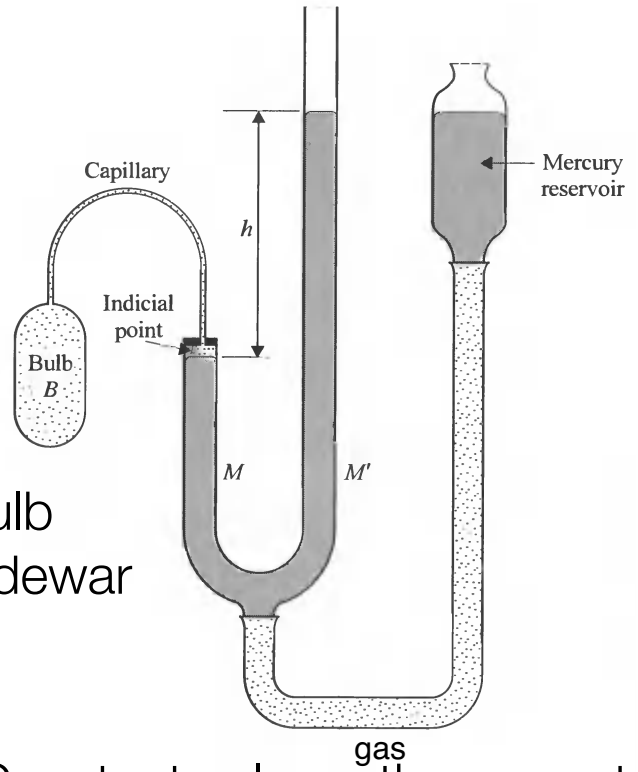
Temperature define by the volume expansion of mercury

$$T_{\text{Celsius}} = C_1 \Delta V / V + C_2$$

The constants are chosen so that freezing is 0 and boiling is 100.



Changes in pressure ratios P/P_{ref} used to define temperature



Gas bulb placed in dewar

Constant volume thermometer

One should decrease the number of moles in the bulb so that the gas behaves like an ideal one. This amounts to trying to reduce Pref at the tripple point.

Place bulb in sample. If the sample is hot, then the gas will try to expand. We then increase the height of the mercury to keep the volume of the gas fixed (at the indicial point). The pressure can be measured from the height of the mercury column.

We can measure pressure ratios and this defines the temperature relative to a reference point.

Triple point of water used as reference point. This is the temperature and pressure where ice water and water vapor are in equilibrium

The triple point of water was defined to be $T = 273.16K$ to have agreement with the celsius scale.

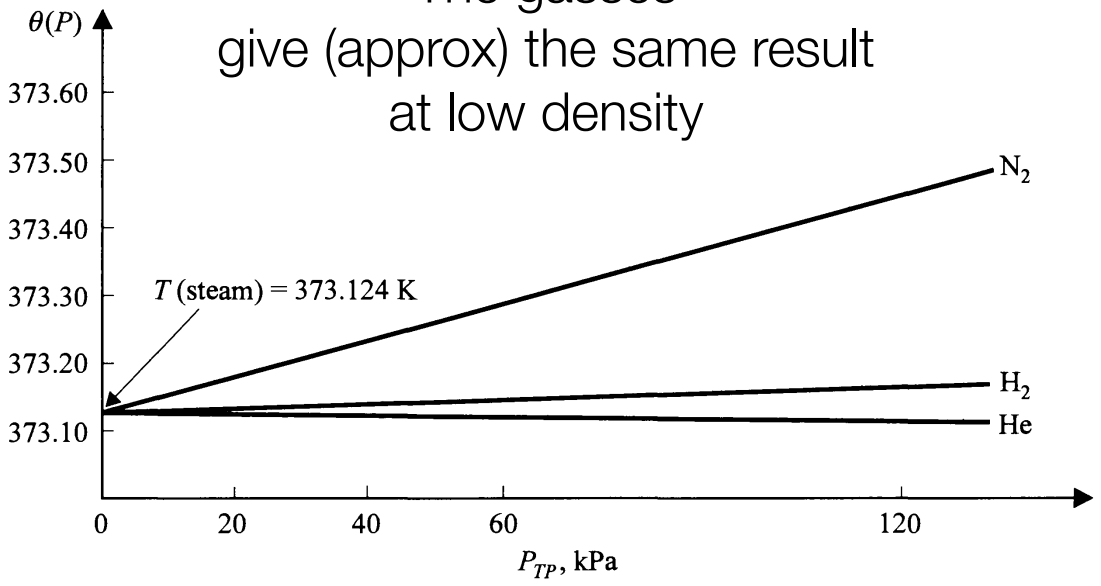
The gas bulb (in the previous slide) is surrounded by water at the triple point, and then the pressure is measured P_{ref}

Then the temperature of steam (for example) can be measured by the ratio

$$\theta \equiv 273.16 \frac{P}{P_{\text{ref}}}$$

with a constant volume thermometer

The gasses
give (approx) the same result
at low density



Pressure in gas bulb at triple point $P_{\text{ref}} \equiv P_{TP}$ is lowered (by reducing the number of atoms in the bulb), extrapolating to the ideal gas limit (infinitely low density). In the limit, the gasses give the same value for the θ parameter, which we call T.

Platinum Resistance Thermometer $4500

Measure the resistance at a given temperature. This is calibrated against an ideal gas thermometer of some kind