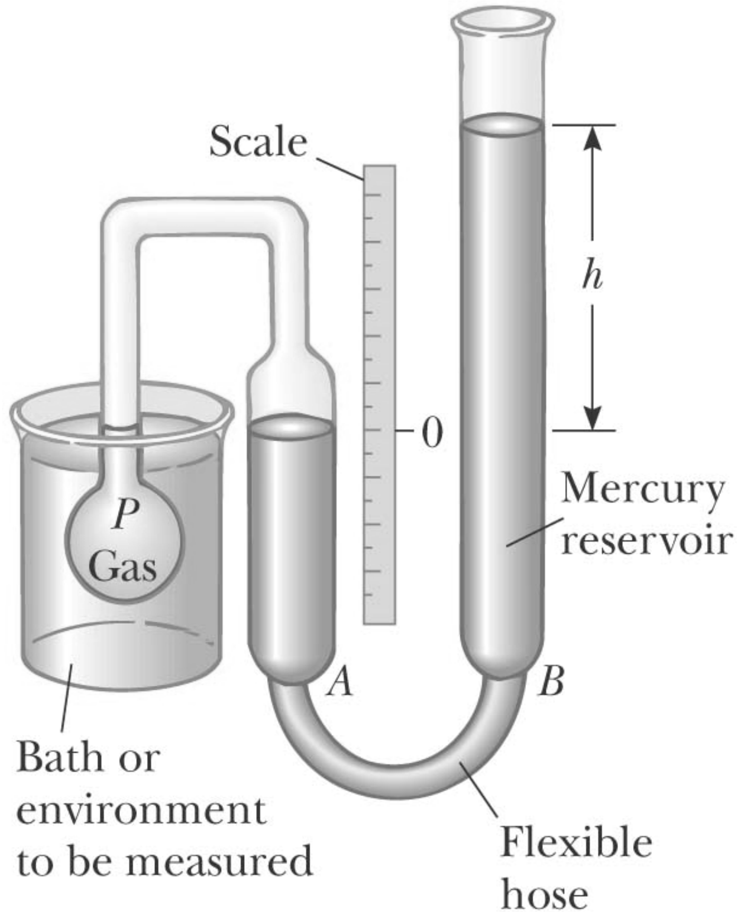
Constant Volume Gas Thermometer

- The physical change exploited is the variation of pressure of a fixed volume gas as its temperature changes

- The volume of the gas is kept constant by raising or lowering the reservoir B to keep the mercury level at A constant

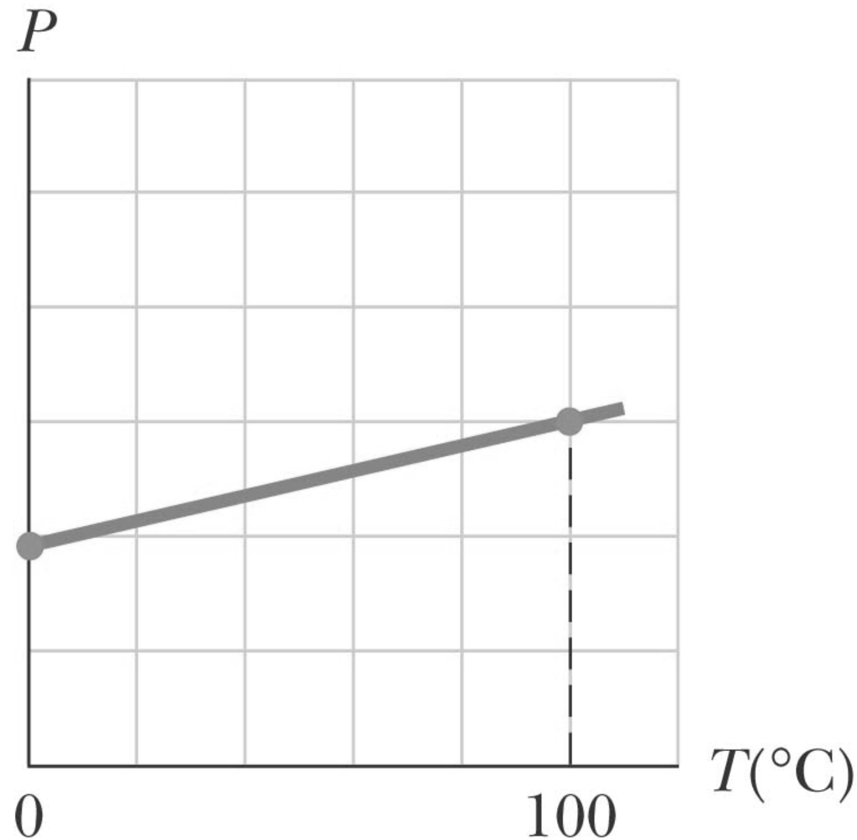


Constant Volume Gas Thermometer

- The thermometer is calibrated by using a ice water bath and a steam water bath
- The pressures of the mercury under each situation are recorded
  - The volume is kept constant by adjusting A
- The information is plotted

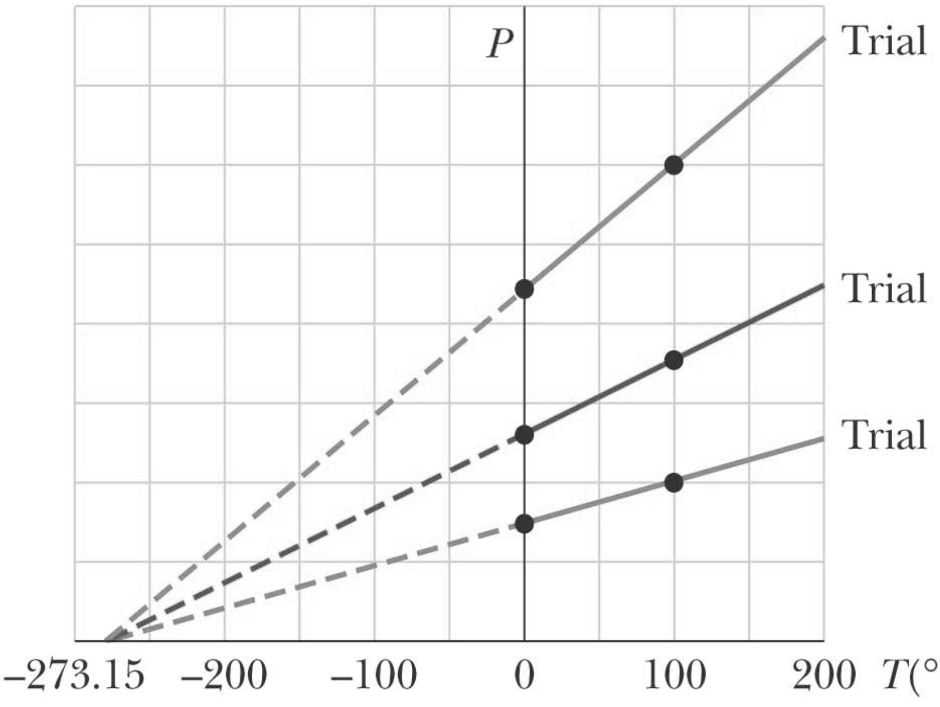
Constant Volume Gas Thermometer

- To find the temperature of a substance, the gas flask is placed in thermal contact with the substance
- The pressure is found on the graph
- The temperature is read from the graph



Absolute Zero

- The thermometer readings are virtually independent of the gas used
- If the lines for various gases are extended, the pressure is always zero when the temperature is –273.15^{o} C
- This temperature is called **absolute zero**



Absolute Temperature Scale

- Absolute zero is used as the basis of the absolute temperature scale
- The size of the degree on the absolute scale is the same as the size of the degree on the Celsius scale
- To convert:

$$\boldsymbol{T_C = T - 273.15}$$

Absolute Temperature Scale, 2

- The absolute temperature scale is now based on two new fixed points
  - Adopted by in 1954 by the International Committee on Weights and Measures
  - One point is **absolute zero**
  - The other point is the **triple point of water**
    - This is the combination of temperature and pressure where ice, water, and steam can all coexist

Absolute Temperature Scale, 3

- The triple point of water occurs at 0.01^{o} C and 4.58 mm of mercury
- This temperature was set to be 273.16 on the absolute temperature scale
  – This made the old absolute scale agree closely with the new one
  – The units of the absolute scale are **kelvins**

Absolute Temperature Scale, 4

- The absolute scale is also called the kelvin scale
  - Named for William Thomson, Lord Kelvin
- The triple point temperature is 273.16 K
  - No degree symbol is used with kelvins
- The kelvin is defined as 1/273.16 of the difference between absolute zero and the temperature of the triple point of water

All gas law problems will be done with Kelvin temperatures.

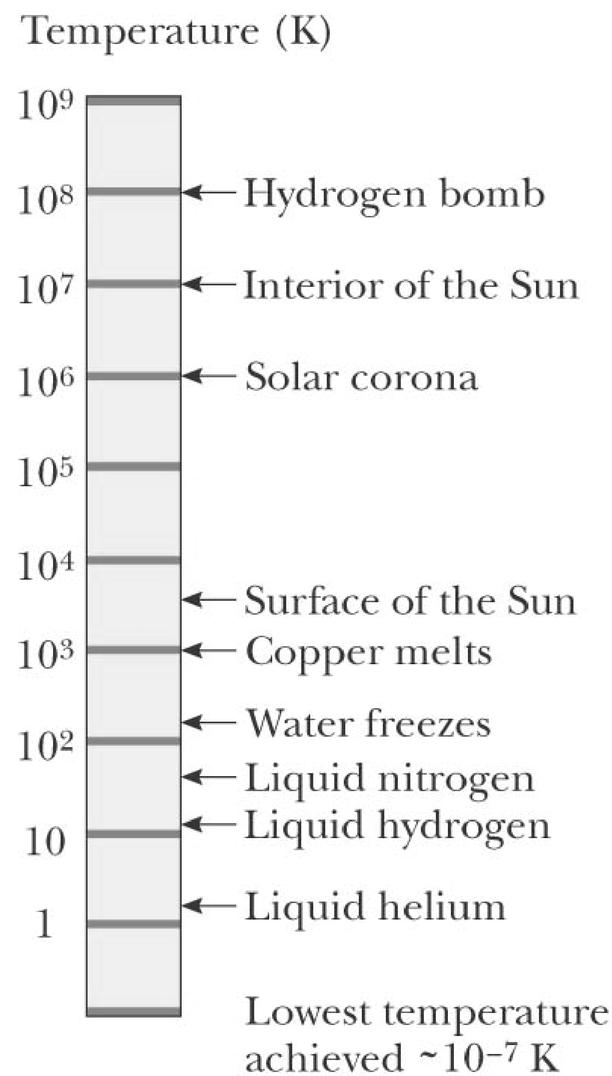
If you were to use degrees Celsius in any of your calculations,

YOU WOULD BE WRONG!!!

Kelvin = Celsius + 273.15.

Some Examples of Absolute Temperatures

- The figure at right gives some absolute temperatures at which various physical processes occur
- The scale is logarithmic
- The temperature of absolute zero cannot be achieved
  - Experiments have come close



Energy at Absolute Zero

- According to classical physics, the kinetic energy of the gas molecules would become zero at absolute zero
- The molecular motion would cease
  - Therefore, the molecules would settle out on the bottom of the container
- Quantum theory modifies this and shows some residual energy would remain
  - This energy is called the **zero-point** energy

Combined gas law

The same amount of ideal gas

Boyle's Law: $P_1 \times V_1 = P_2 \times V_2$

Multiply by **Charles Law**: $V_1 / T_1 = V_2 / T_2$

$P_1 \times V_1^2 / T_1 = P_2 \times V_2^2 / T_2$

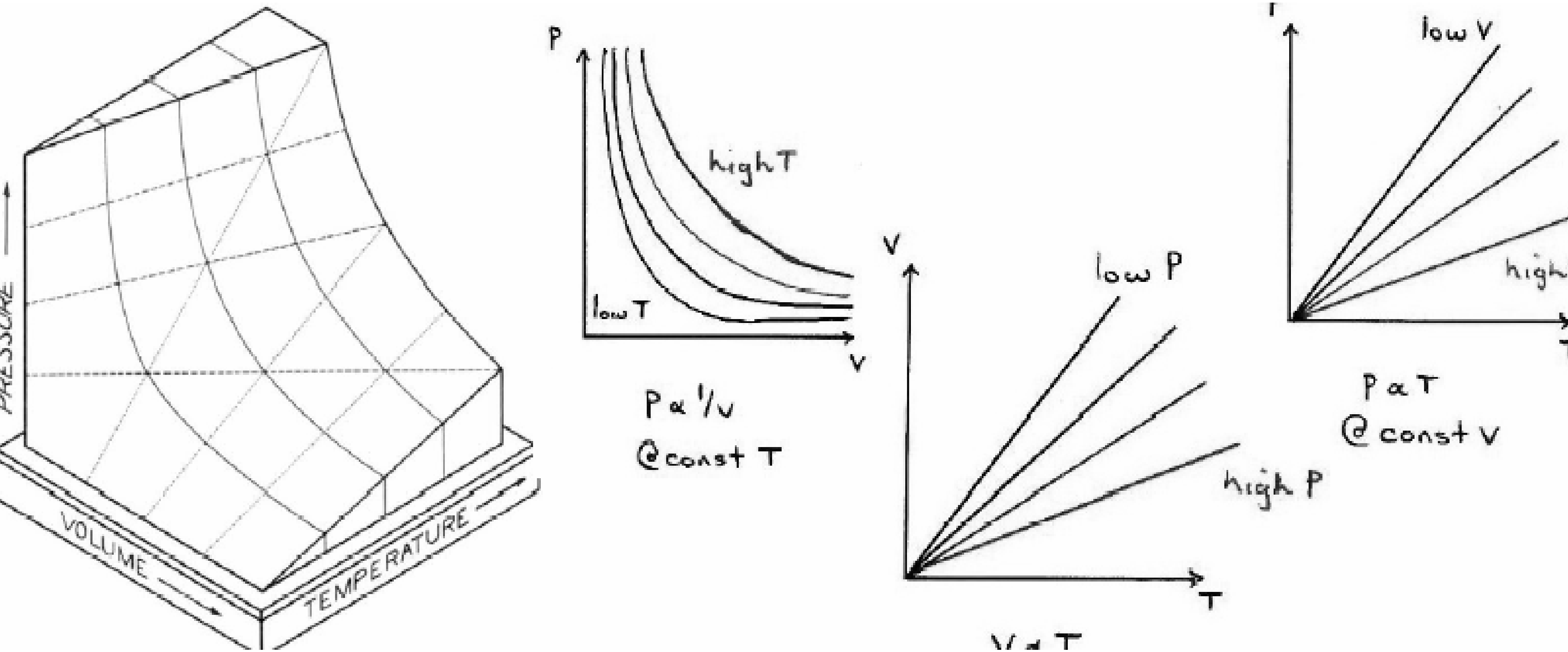
Multiply by **Gay-Lussac's Law**: $P_1 / T_1 = P_2 / T_2$

$P_1^2 V_1^2 / T_1^2 = P_2^2 V_2^2 / T_2^2$

Take the square root to get the combined **Ideal Gas Law:**

$$\mathbf{P_1 V_1 / T_1 = P_2 V_2 / T_2}$$

P,V,T world



PRESSURE
VOLUME
TEMPERATURE
P
V
high T
low T
P ∝ 1/V
@const T
V
T
low P
high P
low V
P ∝ T
@const V

Avogadro's Hypothesis (1812)

Samples of different gases which contain the same number of molecules – of any complexity, size, or shape – occupy the same volume at the same temperature and pressure

Another way of stating Avogadro's idea mathematically is to write:

$$\mathbf{V} = (\text{constant}) \times \mathbf{N}$$

$PV / T = const$

It follows from Avogadro's hypothesis that proportionality

$V = T/P \times N \times const$ or $PV = T \times N \times const$

N = number of gas molecules

can be replaced by an equality with the *same* proportionality constant for *all* gases:

$PV = k \times N \times T$

Where k is called Boltzmann's Constant

The first person to have calculated the number of molecules in any mass of substance was Josef Loschmidt, (1821-1895), an Austrian high school teacher.

In 1865, using the new Kinetic Molecular Theory he calculated the number of molecules in one **cm^3** of gaseous substance under ordinary conditions of temperature of pressure, to be somewhere around **2.6×10^{19} molecules**. This is usually known as **"Loschmidt's Constant."**

This value *is now* **$2.686\,7775 \times 10^{25}\ m^{-3}$**