• Last time: 0-th law. Can tell when 2 systems are at the same temperature $\Theta$. Now use this to build a thermometer and define a temperature scale. Will pick a particular definition of temperature, and call this $T$.

• Equation of state: $f(P, V, T) = 0$. Observed fact: at low densities, all fluids have approximately the same equation of state: $PV - n\phi(T) = 0$. Function $\phi(T)$ depends on definition of $T$. Sensible to take $\phi(T) = aT + b$. All substances have same $a$ and $b$. Could define $T$ such that $a = 1$ and $b = 0$. Instead, we use Kelvin, $\phi(T) = RT_K$, where $R = 8.3143 \times 10^3 J/(kmole)(degK)$, or Celsius/Centigrade, with $T_C = T_K - 273.15$.

• So at low densities, all fluids have equation of state given approximately by the *ideal gas law* (with $T$ in Kelvin)

$$PV = nRT.$$

• Official SI definition of temperature: Fix constant $a = R$ above by a choice of a reference temperature: triple point of water occurs at a unique temperature, which SI defines to be $T_3 \equiv 273.16K$. (Pressure $P_3 = 0.00602atm$.)

• More general equation of state, $f(P, V, T) = 0$ (for equilibrium). Can solve for $P = P(V, T)$, or $T = T(P, V)$, or $V = V(T, P)$.

• Some math:

$$dP = \left(\frac{\partial P}{\partial T}\right)_V dT + \left(\frac{\partial P}{\partial V}\right)_T dV.$$

Divide by $dP$, keeping $T$ constant:

$$1 = \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial P}\right)_T.$$

Divide by $dT$, keeping $P$ constant

$$0 = \left(\frac{\partial P}{\partial T}\right)_V + \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P.$$

Follows that

$$\left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial T}{\partial V}\right)_P \left(\frac{\partial V}{\partial P}\right)_T = -1.$$