

Lecture 37

Phase diagrams.

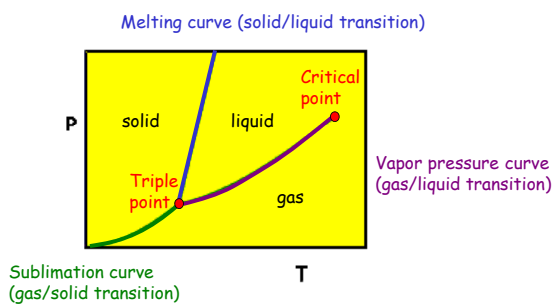
Phase diagrams

Convenient tool to represent **states** and transitions from one state to another.

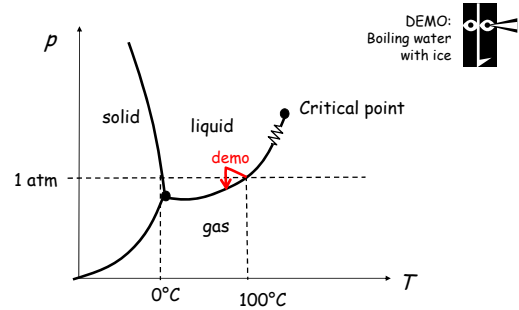
State: system must be in thermal equilibrium.

We can only represent equilibrium (or quasi-equilibrium) situations.

pT diagram



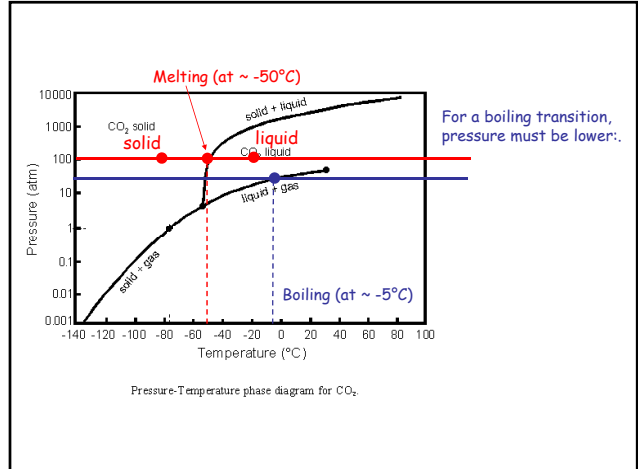
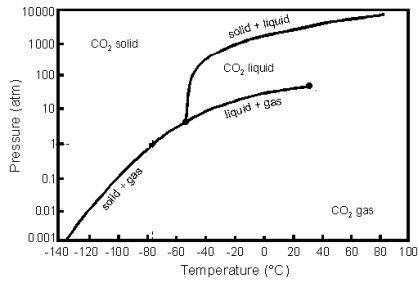
pT diagram for water



In-class example: pT diagram for CO_2

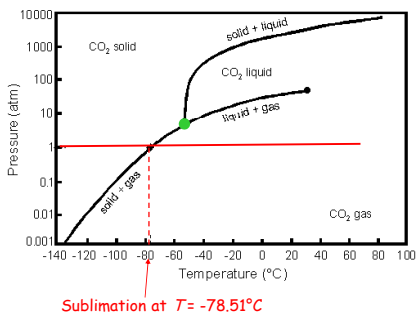
Which of the following states is NOT possible for CO_2 at 100 atm?

- A. Liquid
- B. Boiling liquid**
- C. Melting solid
- D. Solid
- E. All of the above are possible.



Triple point for CO_2 has a pressure > 1 atm.

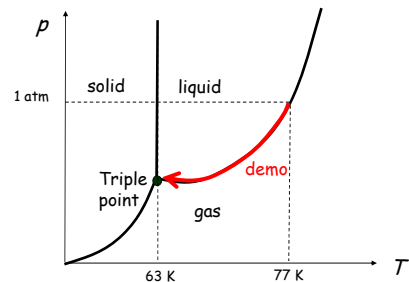
At normal atmospheric pressure (1 atm), CO_2 can only be solid or gas.



pT diagram for N_2

At 1 atm, $T_{\text{boiling}} = 77$ K $T_{\text{melting}} = 63$ K

Triple point for N_2 : $p = 0.011$ atm, $T = 63$ K

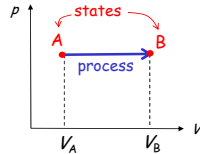


DEMO:
N₂ snow

pV diagrams

Expansion at constant pressure

(isobaric process)



Example: helium in balloon expanding in the room and warming up

If we treat the helium in the balloon as an ideal gas, we can predict T for each state:

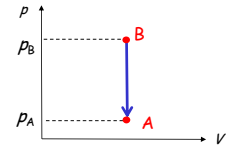
$$T_{A/B} = \frac{pV_{A/B}}{nR}$$



ACT: Constant volume

This pV diagram can describe:

- A. A tightly closed container cooling down.
- B. A pump slowly creates a vacuum inside a closed container.
- C. Either of the two processes.



(isochoric process)

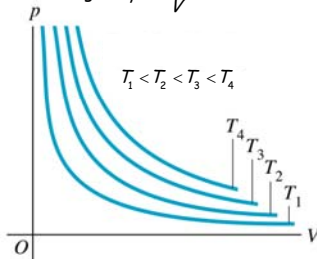
In either case, volume is constant and pressure is decreasing.

In case A, because T decreases.

In case B, because n decreases.

Isothermal curves

For an ideal gas, $p = \frac{nRT}{V}$ (For constant n , a hyperbola for each T)

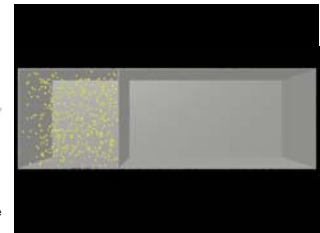
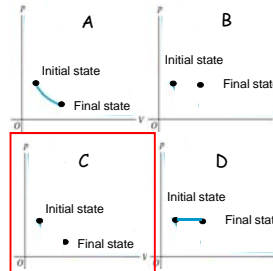


Each point in a pV diagram is a possible state (p, V, T)

Isothermal curve = all states with the same T

ACT: Free expansion

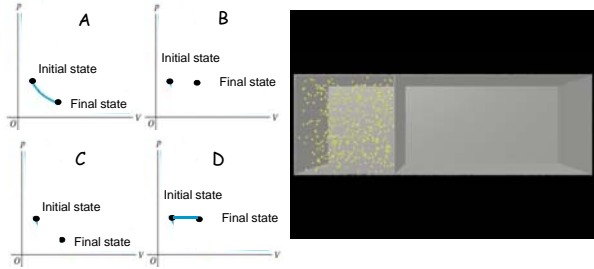
A container is divided in two by a thin wall. One side contains an ideal gas, the other has vacuum. The thin wall is punctured and disintegrates. Which of the following is the correct pV diagram for this process?



Final state has larger V , lower p

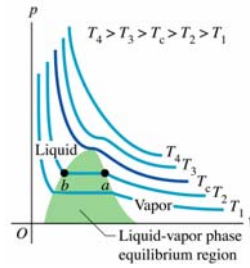
During the **rapid** expansion, the gas does NOT uniformly fill V at a uniform p

- ⇒ hence it is not in a thermal state.
- ⇒ hence no "states" during process
- ⇒ hence this process is **not** represented by line



Beyond the ideal gas

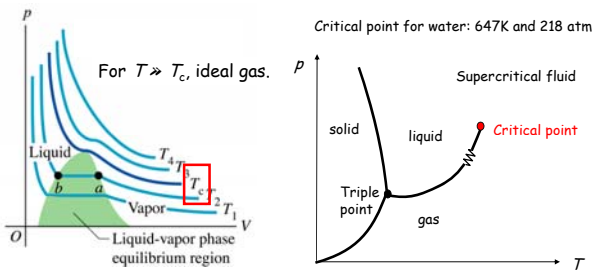
When a real gas is compressed, it eventually becomes a liquid...



Decrease volume at constant temperature T_2 :

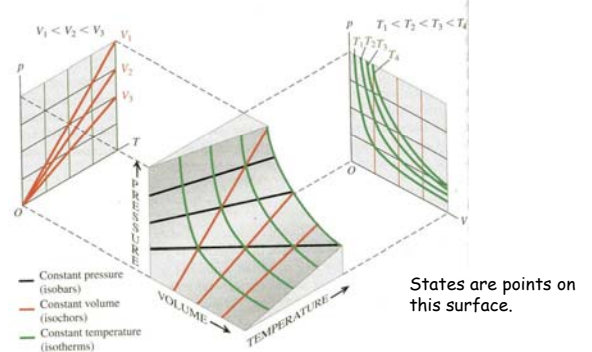
- At point "a", vapor begins to condense into liquid.
- Between a and b: Pressure and T remain constant as volume decreases, more of vapor converted into liquid.
- At point "b", all is liquid. A further decrease in volume will require large increase in p .

The critical temperature



critical temperature = highest temperature where a phase transition happens.

pVT diagram: Ideal gas



States are points on this surface.

pVT diagram: Water

