Phase Transitions
Physics 211

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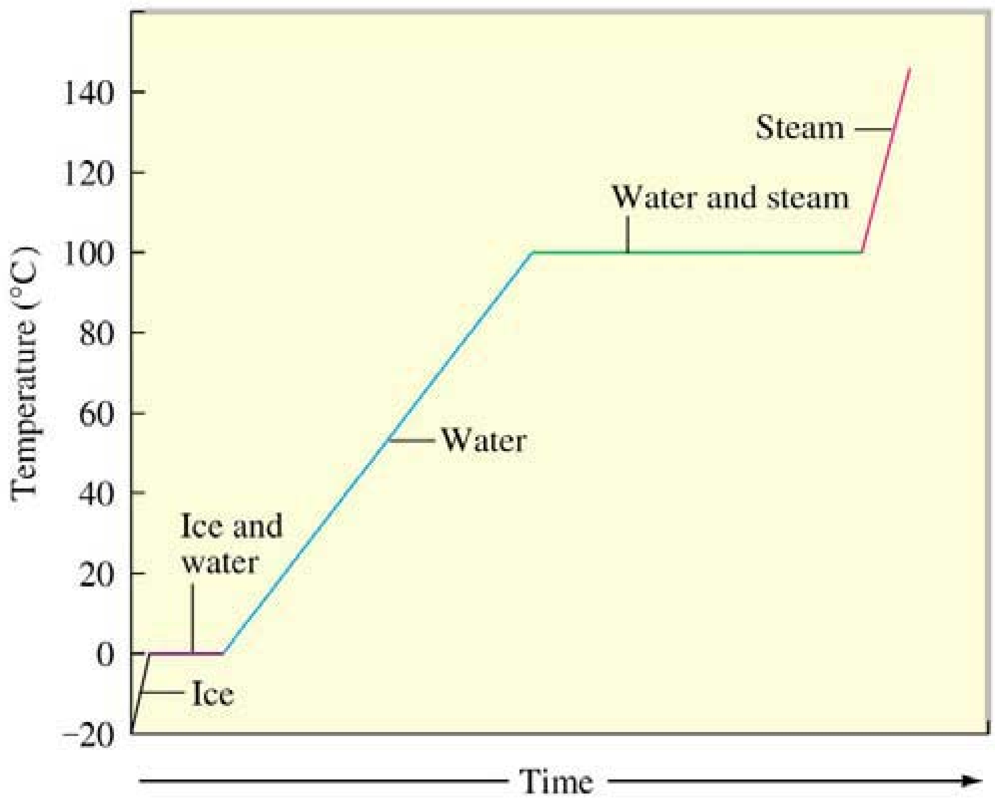
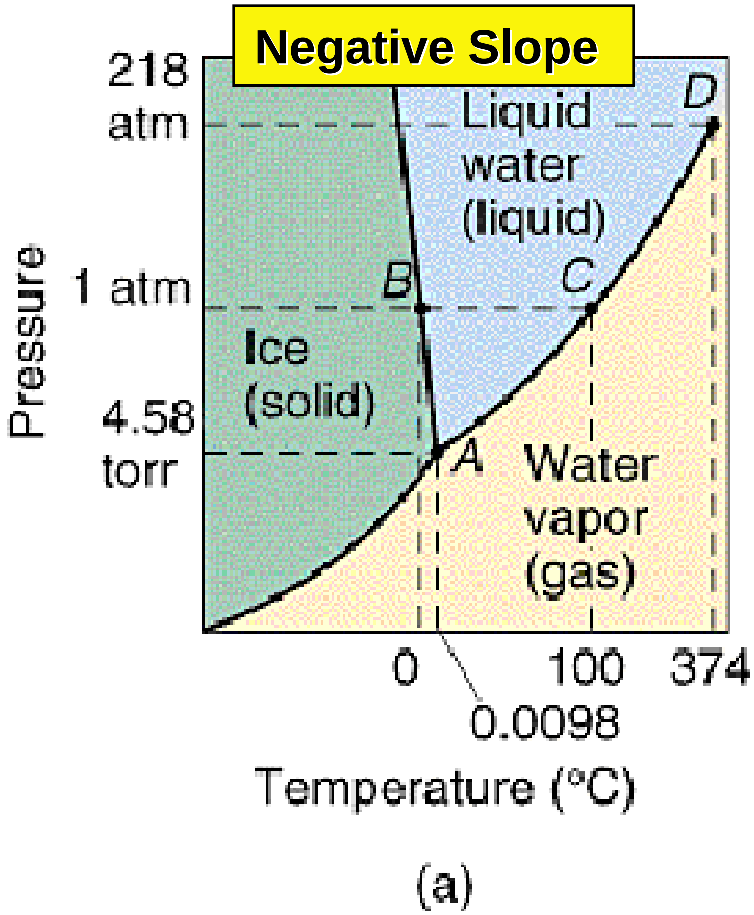
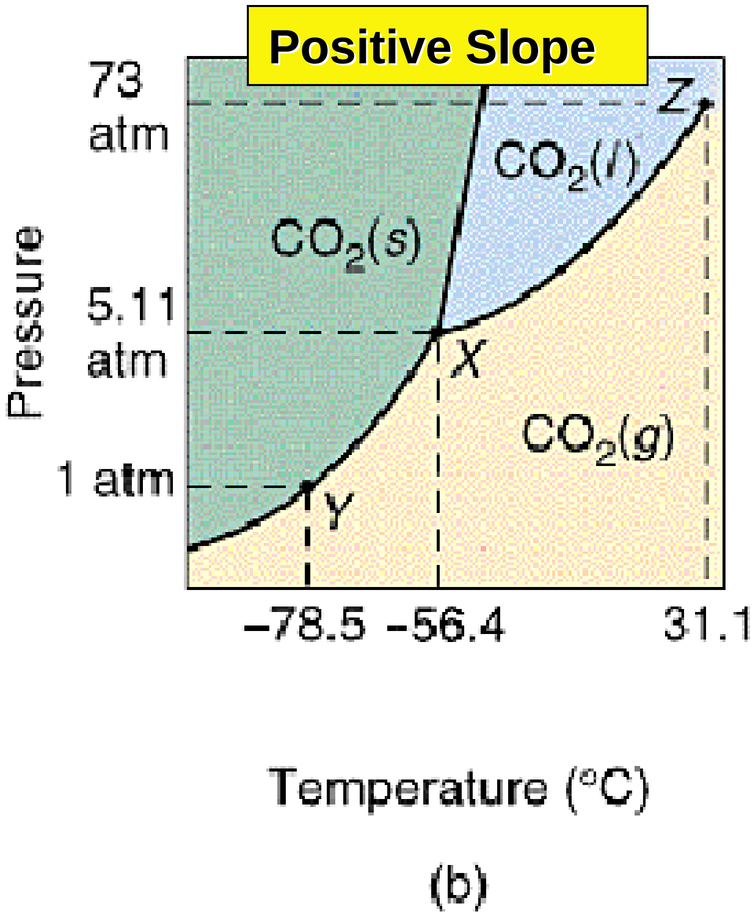
Steam, Water, Ice

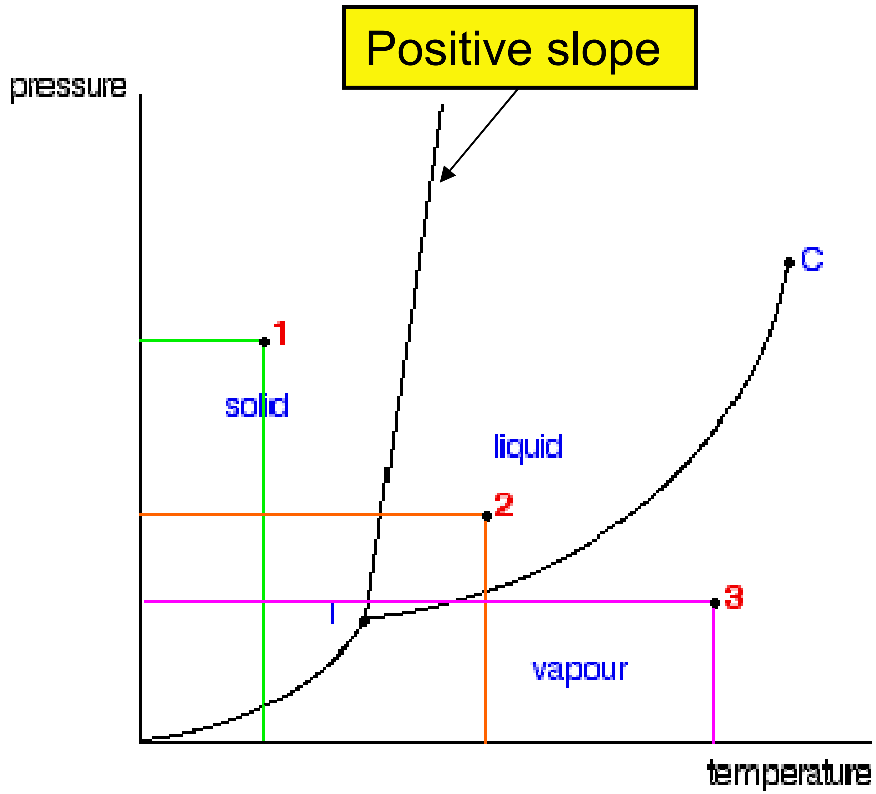


Phase diagram for water and carbon dioxide





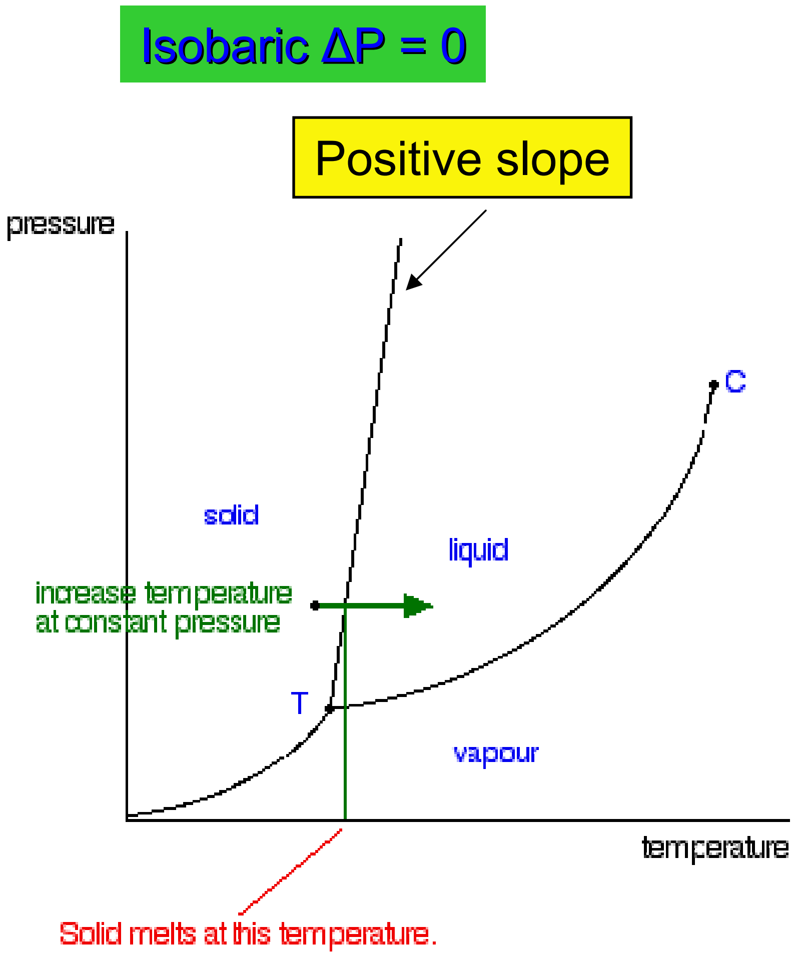
Phase Diagram of a “normal” substance

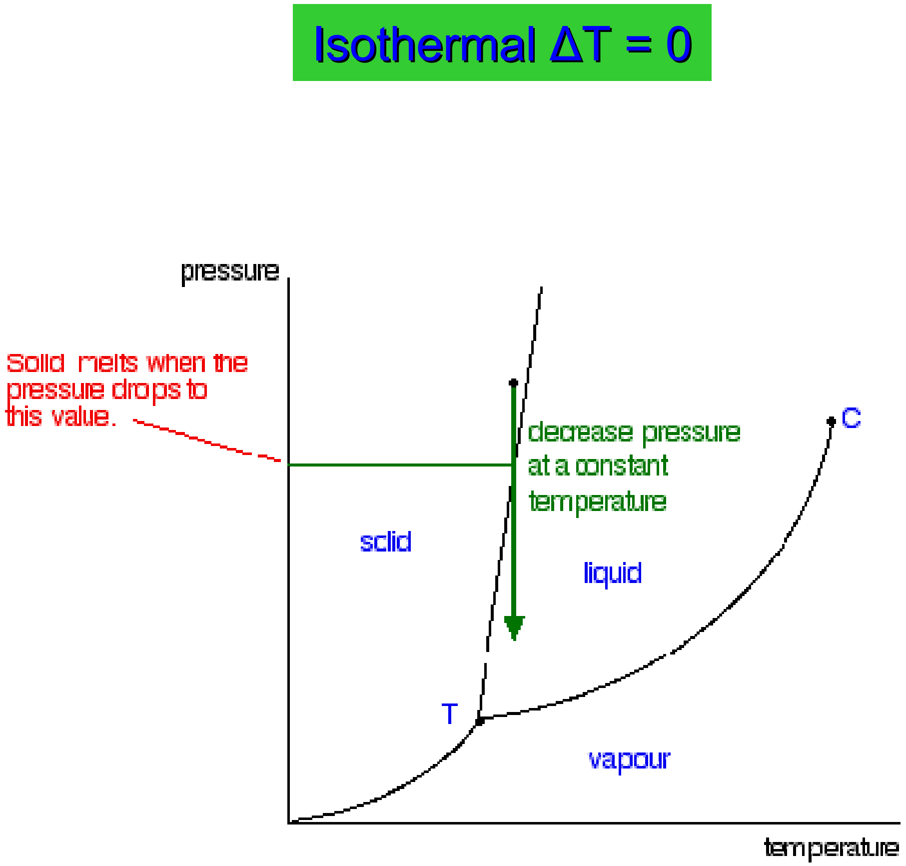


Under the set of conditions at 1 in the diagram, the substance would be a solid because it falls into that area of the phase diagram. At 2, it would be a liquid; and at 3, it would be a vapor (a gas).

See: http://www.chemguide.co.uk/physical/phaseeqia/phasediags.html

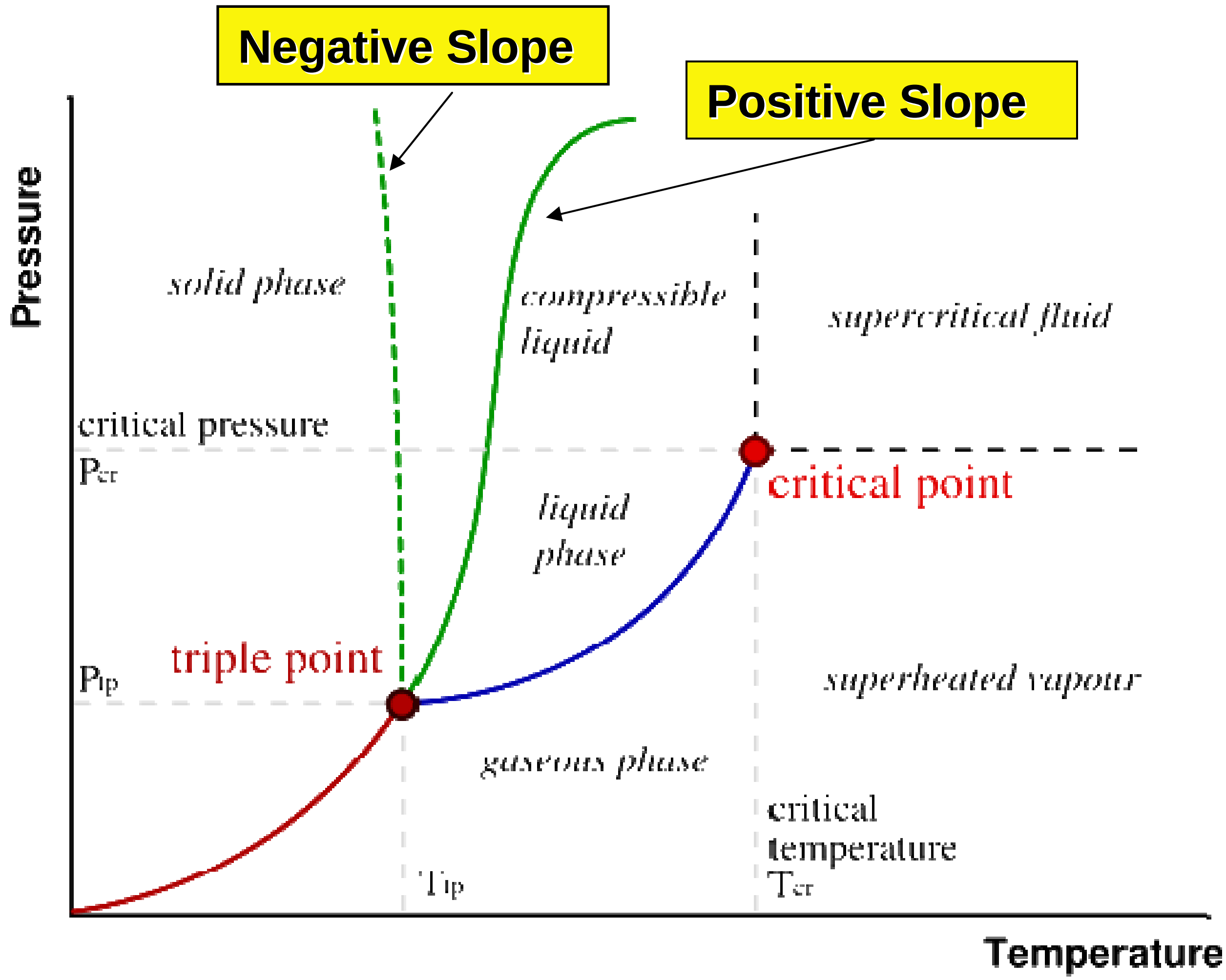
Phase Diagram of a “normal” substance





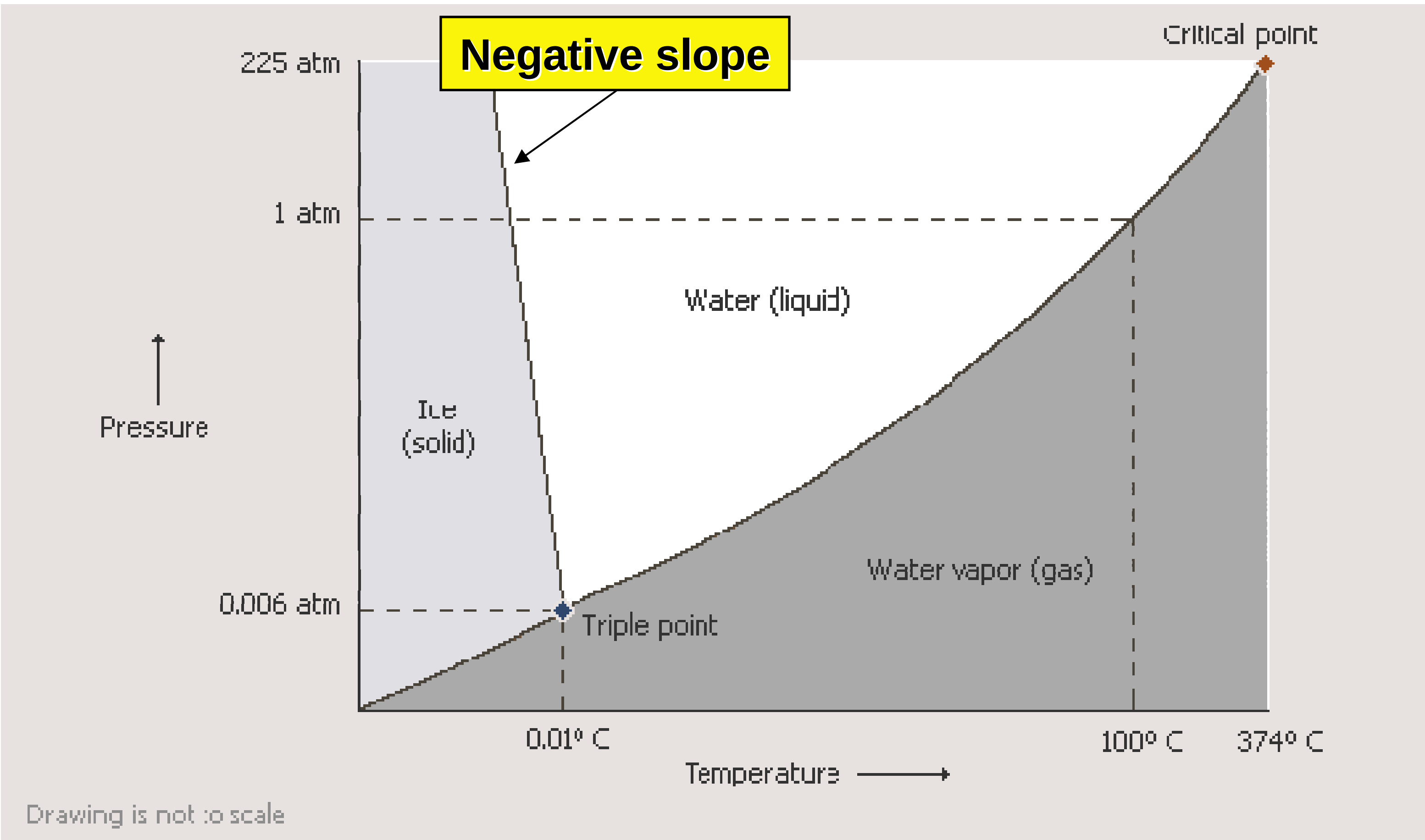
See: http://www.chemguide.co.uk/physical/phaseeqia/phasediags.html

PHASE DIAGRAM in full and glorious detail



A typical phase diagram. The **dotted** line gives the anomalous behavior of water. The green lines mark the **freezing point** and the blue line the boiling point, showing how they vary with pressure.

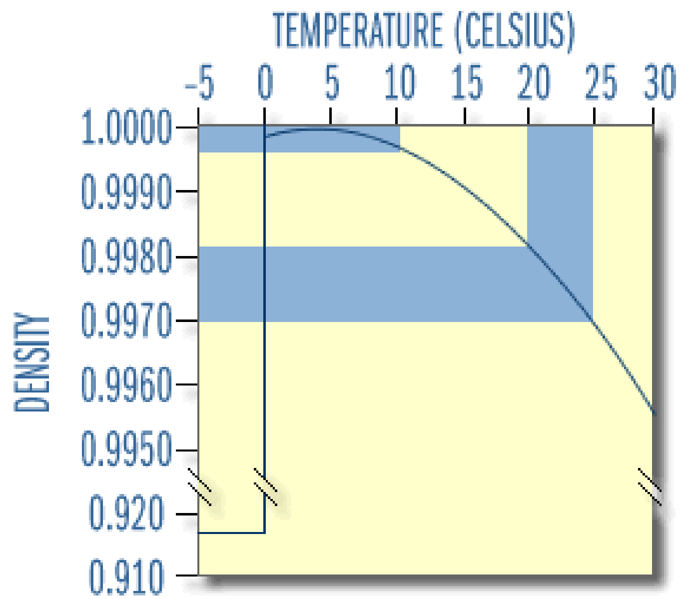
Water, water, everywhere



Liquid to Solid Phase of Water is Anomalous

- As most compounds change from a liquid to a solid, the molecules become more tightly packed and consequently the compound is denser as a solid than as a liquid. Water, in contrast, is most dense at 4°C and becomes less dense at both higher and lower temperatures.

- Water differs from most other compounds because it is less dense as a solid than as a liquid. Consequently ice floats, while water at temperatures just above freezing sinks. The denser water at 4°C sinks and lower temperature water stays at the top. That is to say lakes freeze from the surface down as depicted in the figure below.



DENSITY/TEMPERATURE RELATIONSHIP FOR DISTILLED WATER. SHADED AREAS SHOW RELATIVE DIFFERENCE IN DENSITY FOR 5°C TEMPERATURE CHANGES.

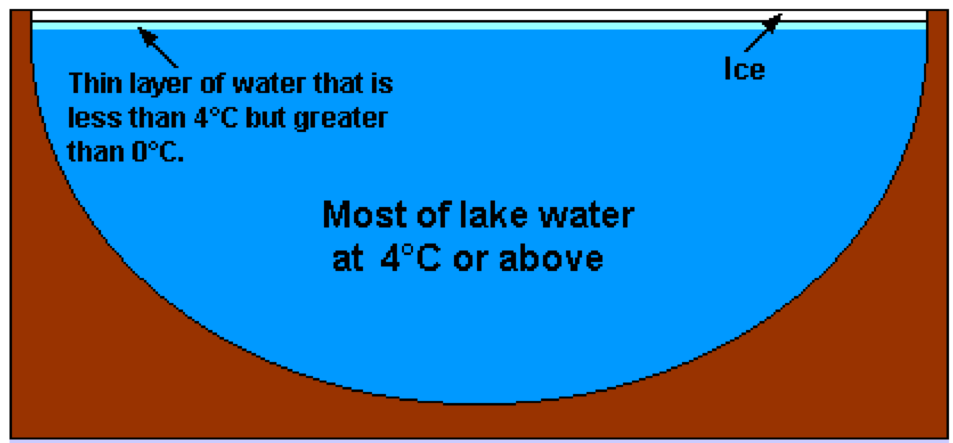


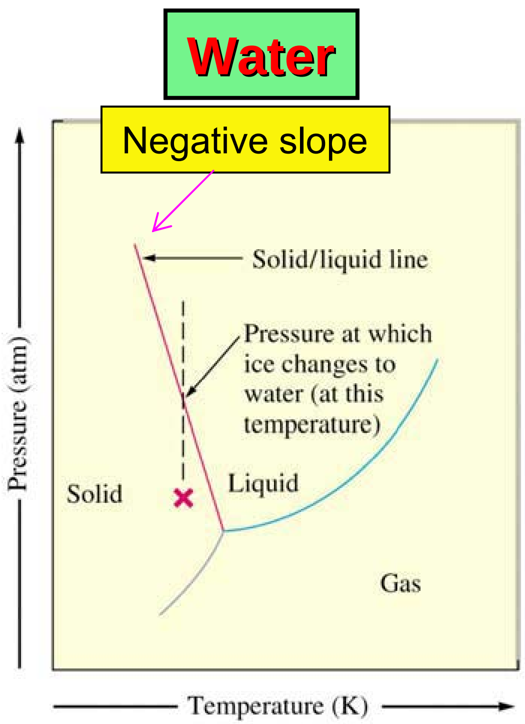
Figure 6 During the winter, ice prevents lake water mixing. Stratification can occur during this time of winter stagnation.

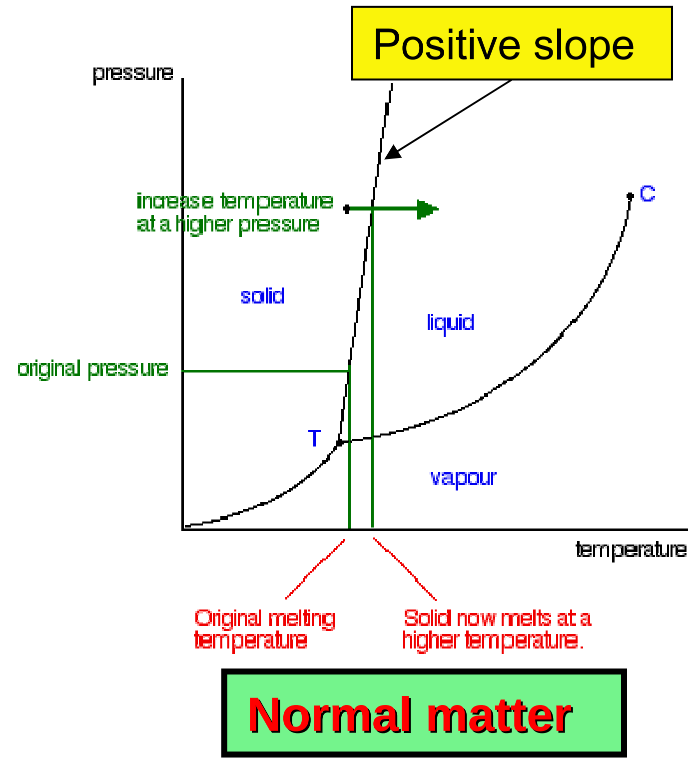
http://waterontheweb.org/under/lakeecology/05_stratification.html

http://faculty.gvsu.edu/videticp/stratification.htm

Melting curve of water is very special

- It has a negative slope due to that when ice melts, the molar volume decreases.
- Ice melts at lower temperatures at higher pressures.
- Ice skates are pressure amplifiers.
- A liquid is formed between the skate and the ice. This liquid acts as a lubricant allowing the skater to skate…



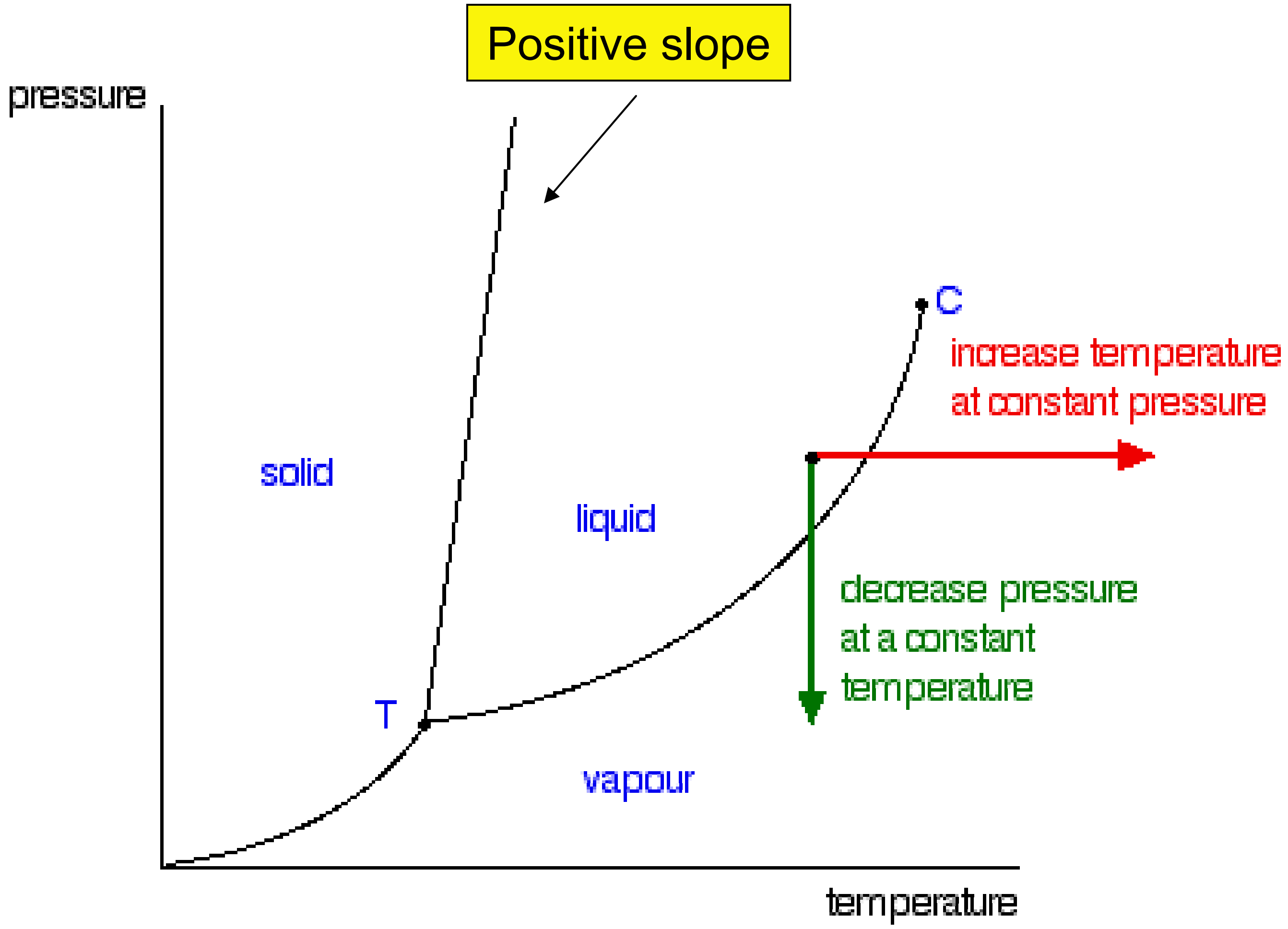


- Why does water boil at lower temperatures at higher elevations? (N.B. 1 atm = 760 Torr)

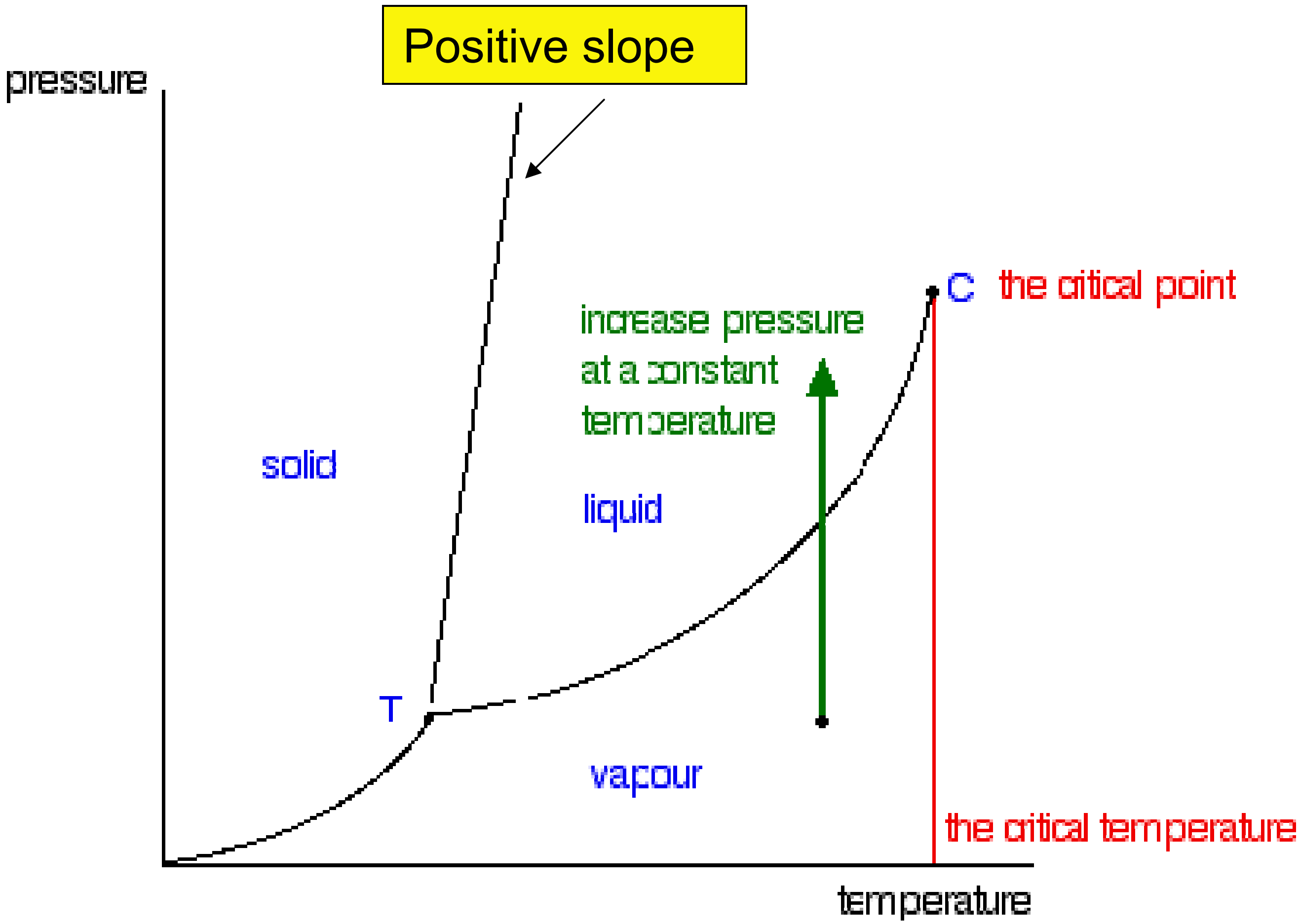
TABLE 16.9 Boiling Point of Water at Various Locations

Location	Feet Above Sea Level	P_{atm} (torr)	Boiling Point (°C)
Top of Mt. Everest, Tibet	29,028	240	70
Top of Mt. McKinley, Alaska	20,320	340	79
Top of Mt. Whitney, Calif.	14,494	430	85
Leadville, Colo.	10,150	510	89
Top of Mt. Washington, N.H.	6,293	590	93
Boulder, Colo.	5,430	610	94
Madison, Wis.	900	730	99
New York City, N.Y.	10	760	100
Death Valley, Calif.	−282	770	100.3

Boil, Boil, Toil and Trouble

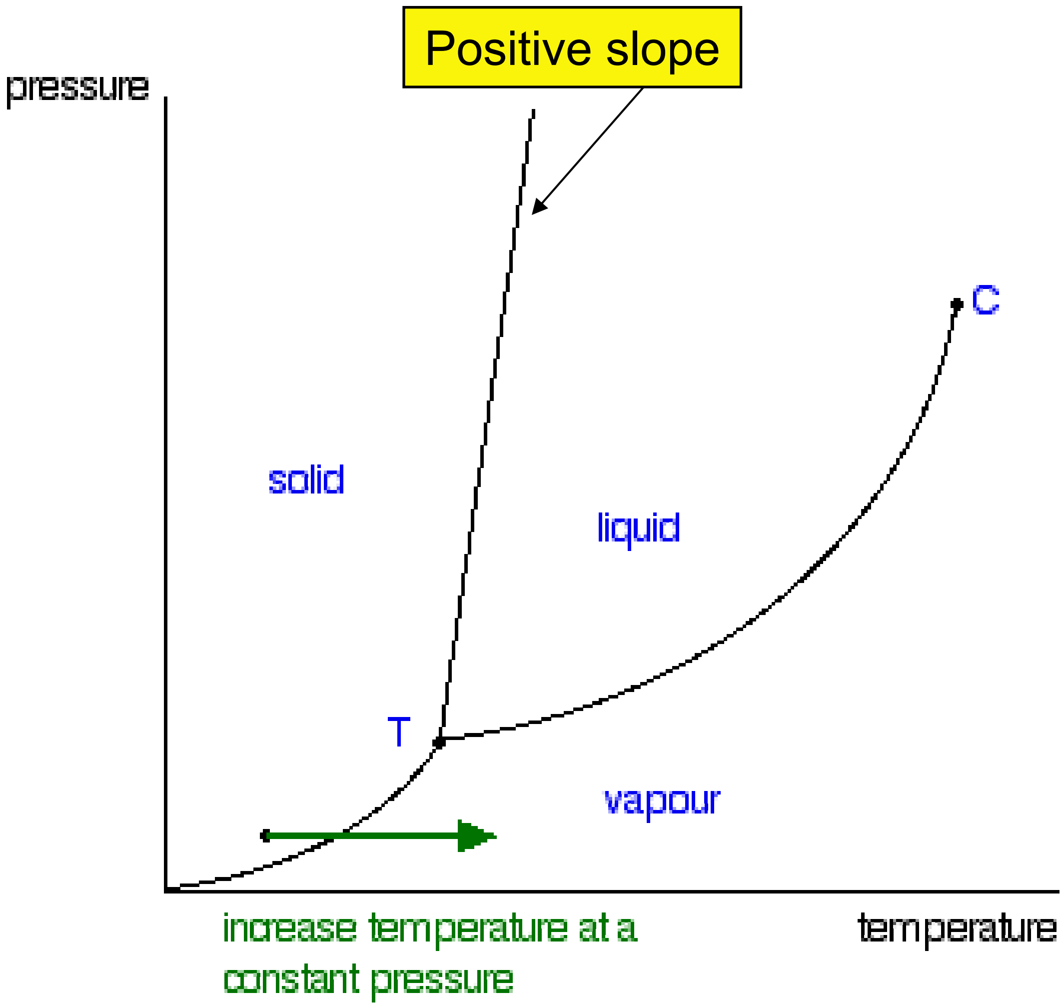


Critical Temperature/Point

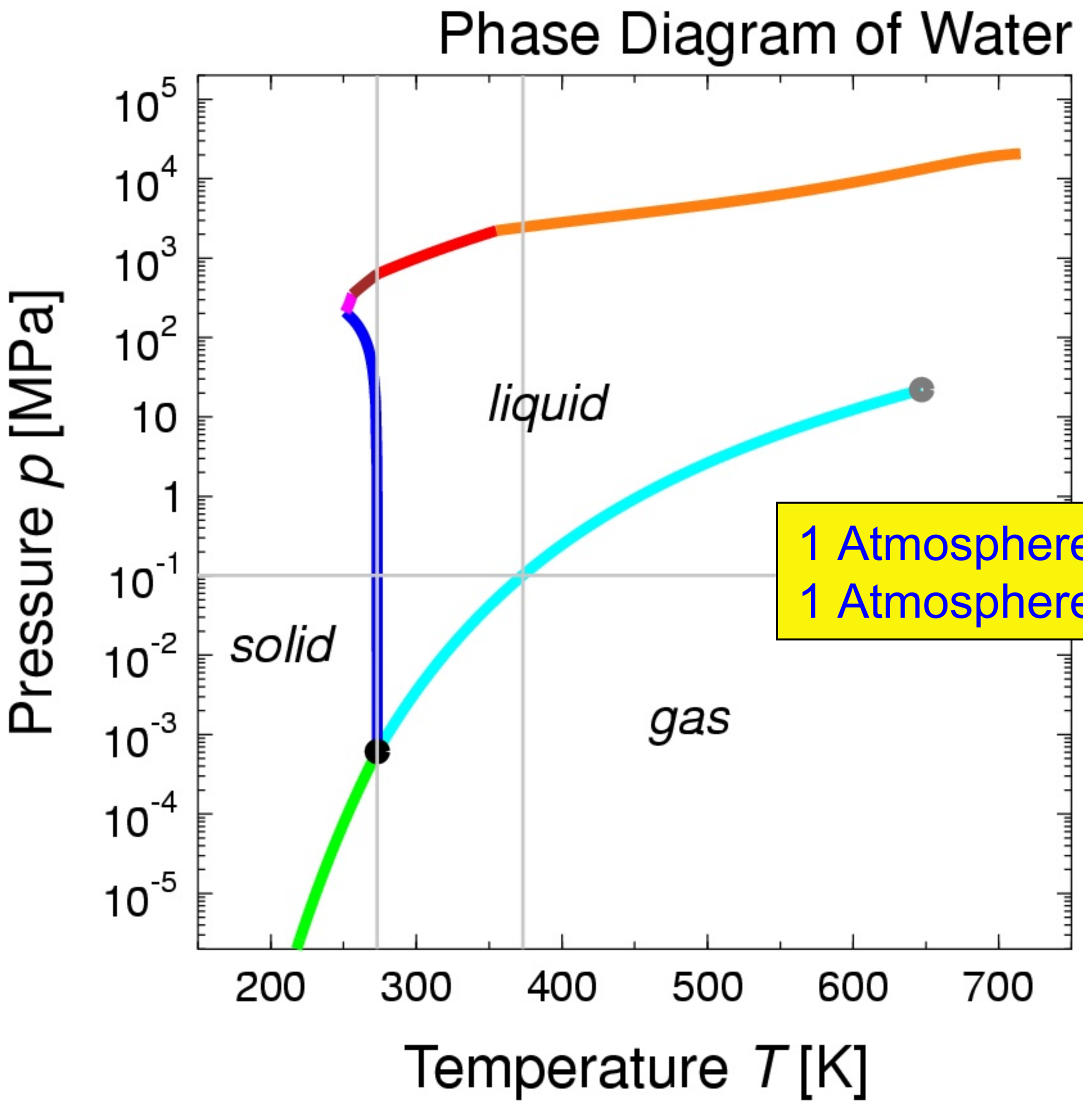


Above the critical temperature the gas cannot be condensed. You just get highly compressed gas.

Sublimation: Moving from solid to vapor without going through the liquid phase.



Normal melting and boiling points



1 Atmosphere = 101,325 Pa
1 Atmosphere = 760 Torr

A **Pressure-Temperature Diagram** is a map of coexisting phases of a material in a closed system. This is called a **Phase Diagram**

Phase boundaries (solid / liquid, liquid / gas, solid / gas)

- critical point (T_c, P_c).

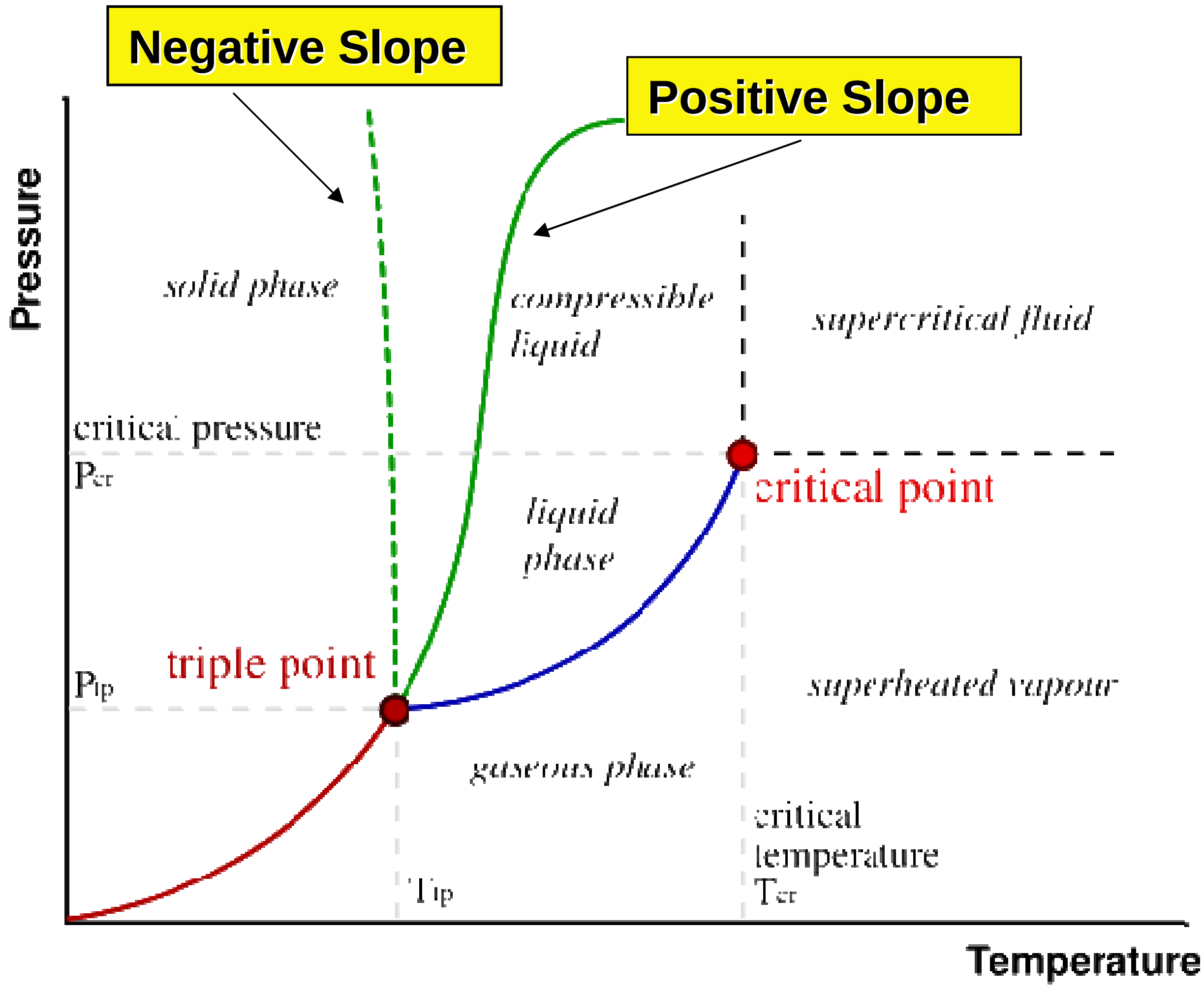
  At temperatures exceeding 647 K, water cannot be liquified.

- triple point (all three states / phases in equilibrium)

  For water this occurs at 273.16 K and 0.006 atm (4.58 Torr).

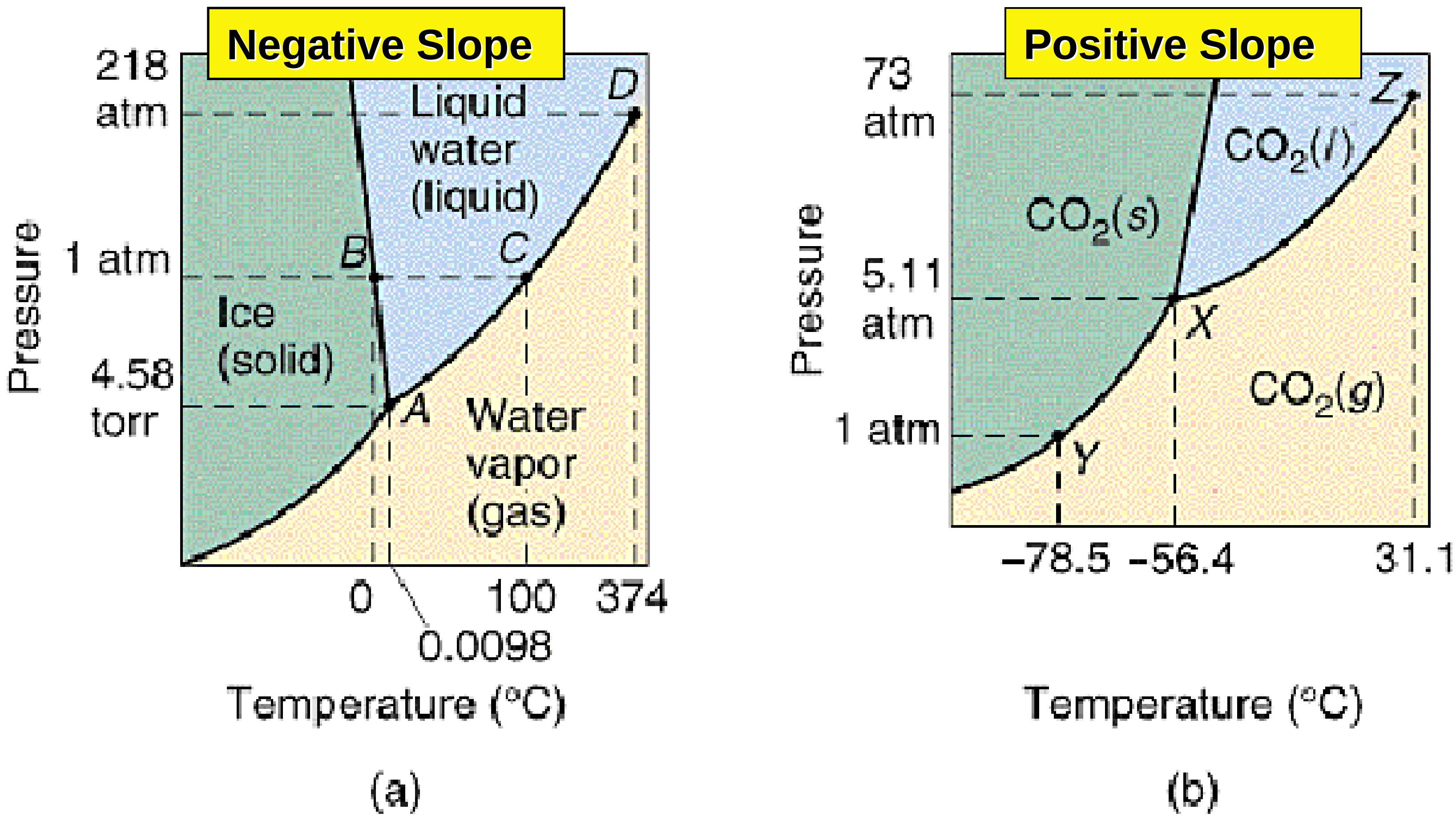
- **Sublimation Curve** separates solid from gas.
- **Vaporization Curve** separates gas from liquid (or Boiling)
- **Melting curve** separates liquid from solid

PHASE DIAGRAM in full and glorious detail

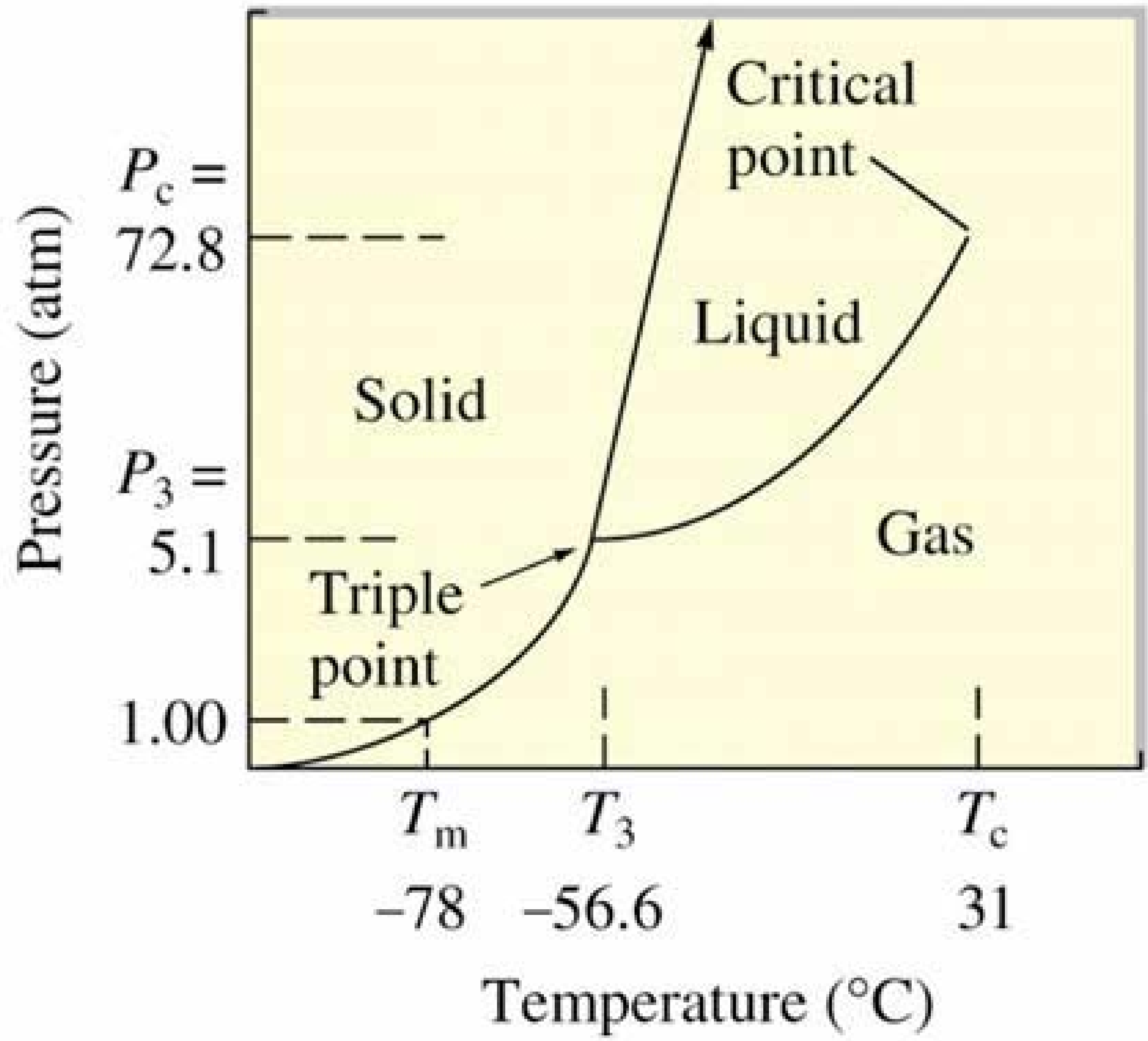


A typical phase diagram. The **dotted** line gives the anomalous behavior of water. The green lines mark the **freezing point** and the blue line the boiling point, showing how they vary with pressure.

Phase diagram for water and carbon dioxide



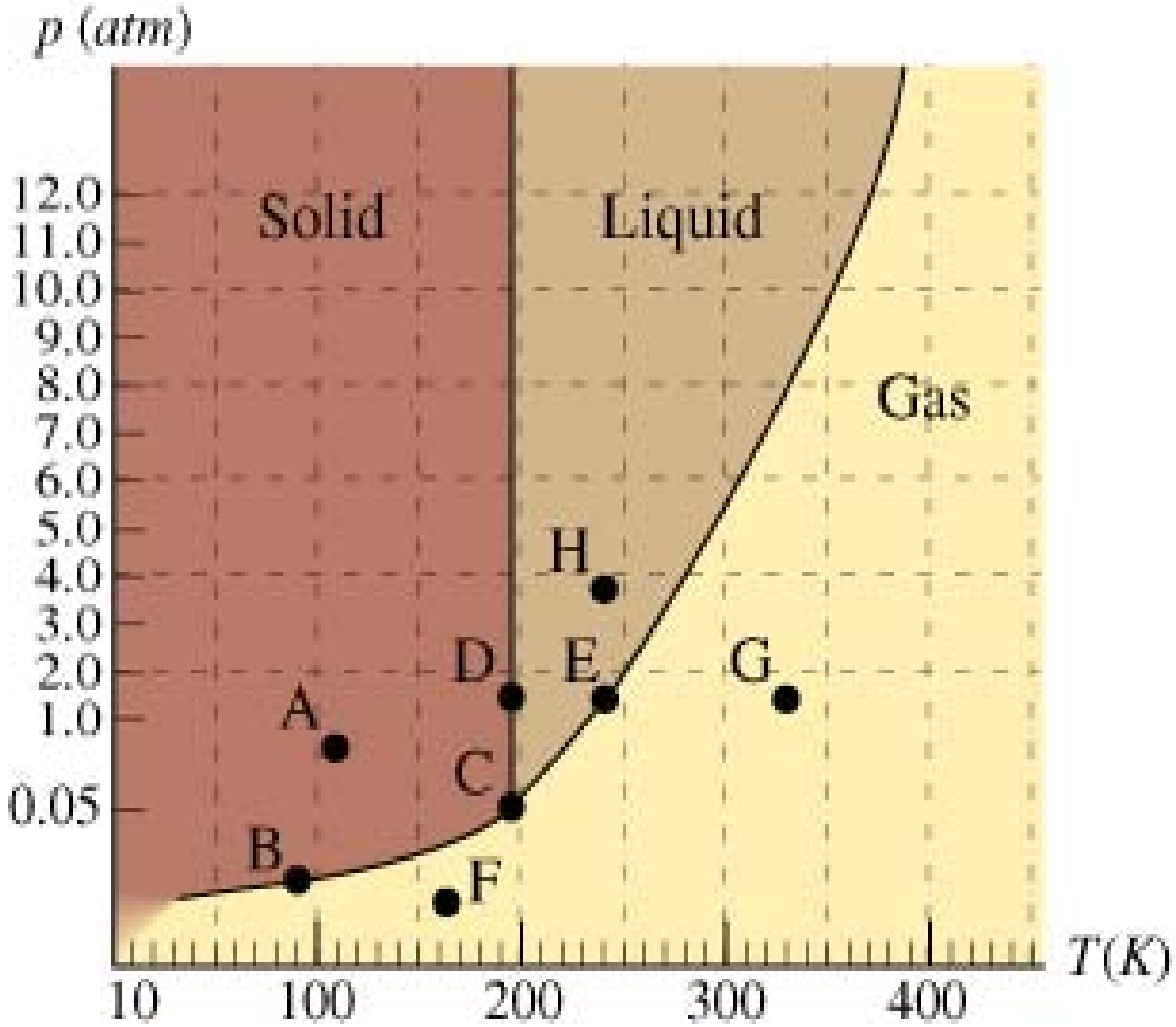
Phase Diagram for Carbon Dioxide



Questions

- What is the melting point of carbon dioxide for a pressure that is greater that 10.0 atm?
- What is the temperature of dry ice at 1.0 atm?
- Can you turn solid CO_2 into liquid form by applying pressure? Why or why not?

AMMONIA (NH_3)

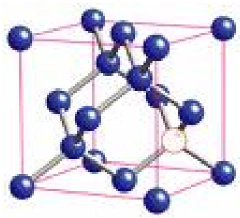


p (atm)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.05
Solid
Liquid
Gas
A
B
C
D
E
F
G
H
T(K)
10
100
200
300
400

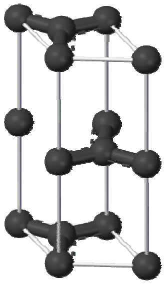
Questions

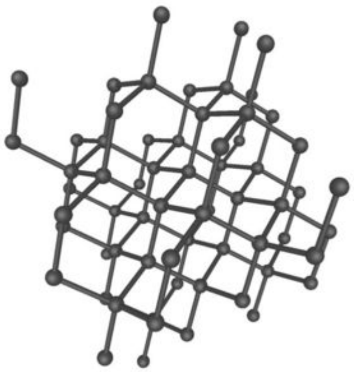
- The line between which two points would describe a process of liquid ammonia boiling completely away.
- On the phase diagram, which section of curve represents the pressure and temperature values at which ammonia will melt
- The line between which two points would describe a process of sublimation for ammonia
- At one atmosphere of pressure and temperatures above -33.3° C (239.7 K), ammonia exists as a gas. For transportation, ammonia is stored as a liquid under its own vapor pressure. This means that the liquid and gas phases exist simultaneously. If a container of ammonia is transported in a temperature-controlled truck that is maintained at no greater than 330 K, what maximum pressure P must the sides of the container be able to withstand?

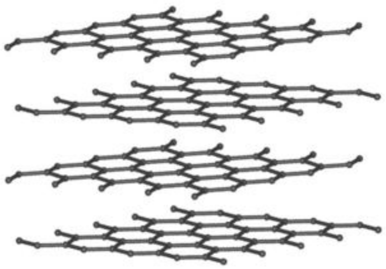
- When compared to almost any other material, diamond almost always comes out on top.
- As well as being the hardest known material, it is also the least compressible, and the stiffest material
- the best thermal conductor with an extremely low thermal expansion
- chemically inert to most acids and alkalis, transparent from the deep UV through the visible to the far infrared,
- and is one of the few materials known with a *negative* electron affinity (or work function).



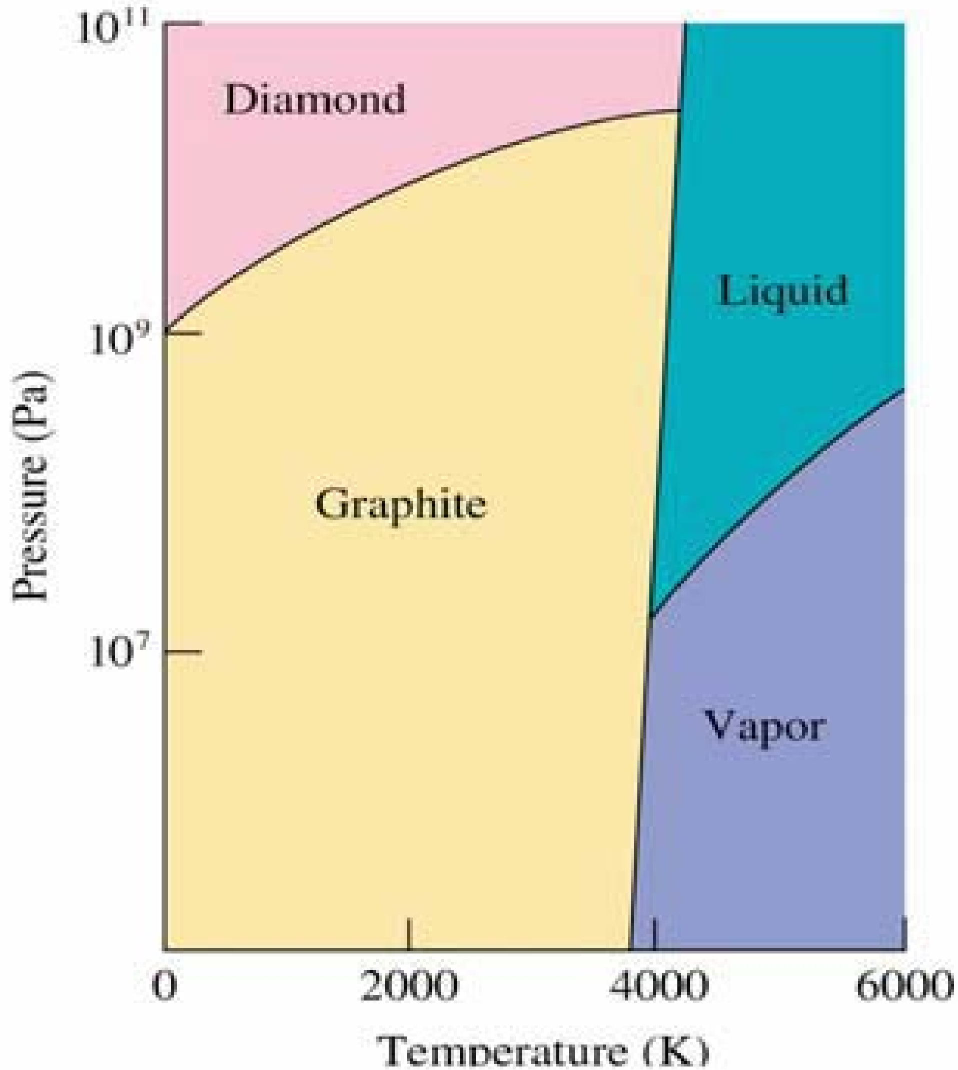
Diamond and graphite: both made of carbon



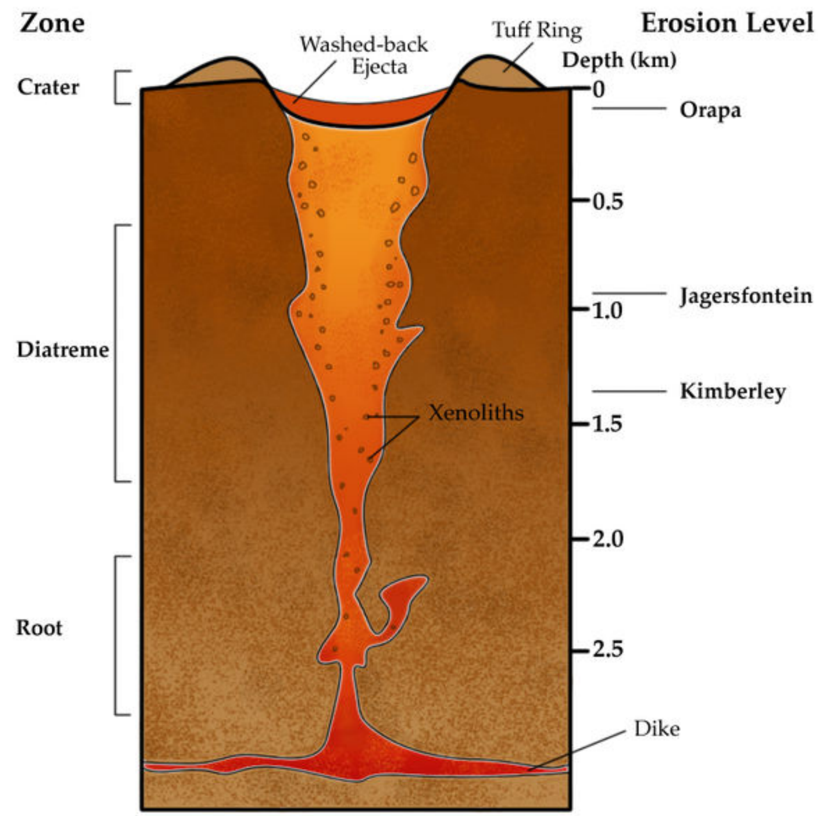




- In diamond we have the hardest known material
- In graphite we have one of the softest materials, simply by rearranging the way the atoms are bonded together.



Diamond
Liquid
Graphite
Vapor
10^{11}
10^9
10^7
Pressure (Pa)
0
2000
4000
6000
Temperature (K)



Zone
Crater
Diatreme
Root
Washed-back Ejecta
Tuff Ring
Xenoliths
Dike
Erosion Level
Depth (km)
0
0.5
1.0
1.5
2.0
2.5
Orapa
Jagersfontein
Kimberley