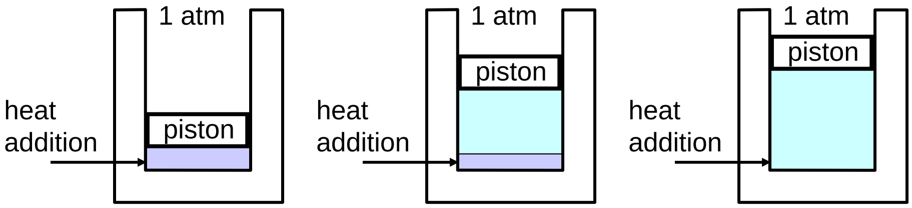
III. Evaluating Properties

A. Definition of a Pure Substance
  1. fixed chemical composition throughout
  2. examples
    dry air (yes)
    root beer float (no)
    water and ice (yes)
    mix of gaseous and liquefied air (no)
    water and steam (yes)
    N_2 (yes)
B. Phases of a Pure Substance
  1. Solid, liquid, gas (for water we have ice, water, and steam)

III. Evaluating Properties

2. Example of a process involving change of phase. Start with liquid water at 25 °C, 1 atm, in cylinder fitted with weightless, frictionless piston. Add heat until liquid completely vaporizes.



Initially 100% liquid at 25 C. This is called compressed liquid state.

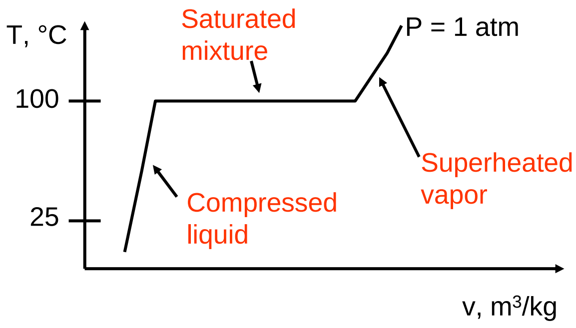
Saturated mixture of liquid and vapor at 100 C

Superheated vapor at T > 100 C

III. Evaluating Properties

2. Example of a process involving change of phase

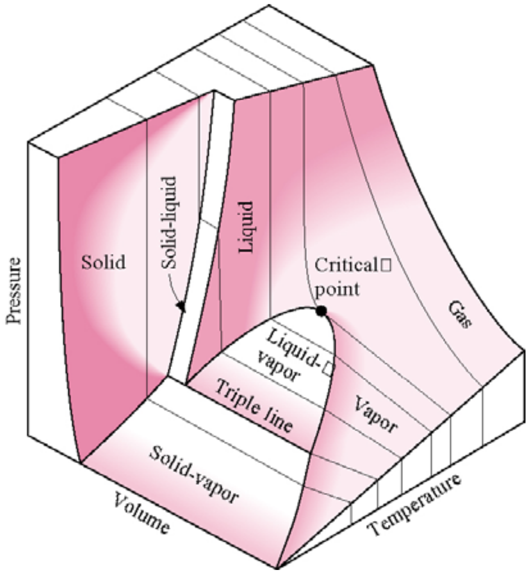
Plot of process on T-v diagram. The temperature does not change when two phases are present.



III. Evaluating Properties

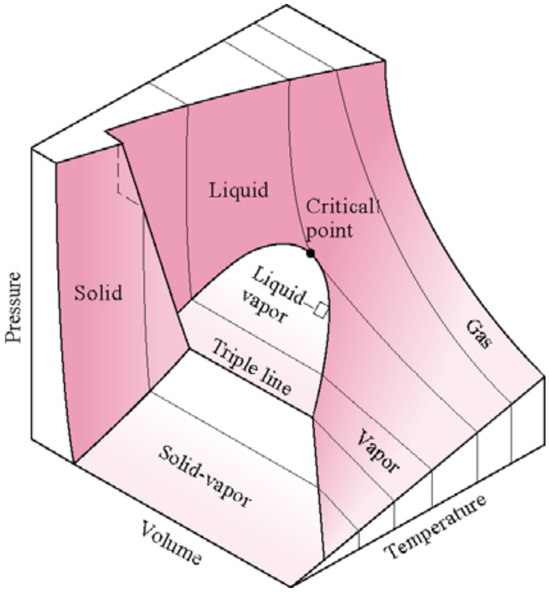
C. The P-v-T Surface

1. a substance which contracts on freezing (Figure 3-26, p. 125). Note that all phases are separated by two-phase regions.



III. Evaluating Properties

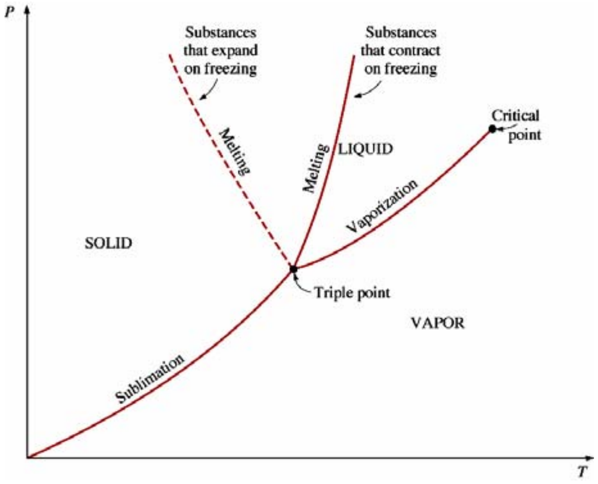
2. a substance which expands on freezing (Fig. 3-27, p. 125). Note that all phases are separated by two-phase regions. Three phases are present along the triple line.



III. Evaluating Properties

D. The P-T Diagram

1. Also called a phase diagram
2. For a substance that expands on freezing, the melting point decreases with increasing pressure
3. The T and P along the vaporization curve are called saturation T and saturation P (T_{sat} and P_{sat})



(Fig. 3-25, p. 124)

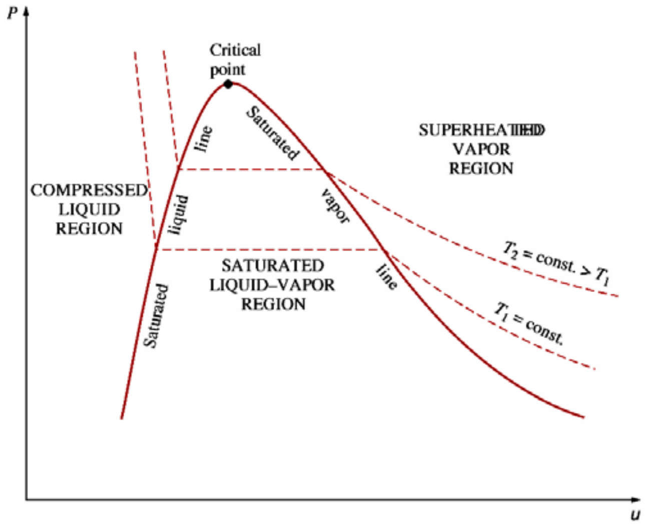
III. Evaluating Properties

4. Low friction sports and Fig. 3-25 for a substance that expands on freezing
   - a. ice skating - skates slide on a thin layer of liquid water. The liquid layer forms under the blade because of the pressure exerted by the blade on the surface of the ice.
   - b. skiing/boarding - skis usually do not exert enough pressure on the snow to cause melting. The melting is due to the shearing of the water layer which generates enough heat to maintain a liquid.

III. Evaluating Properties

E. The P-v Diagram

1. The two-phase, liquid-vapor region lies between the saturated liquid and saturated vapor lines



(Fig. 3-19, p. 121)

III. Evaluating Properties

2. Saturation temperature and pressure for water. The saturation pressure is also called the vapor pressure. See Tables A-4, 5.

In the saturation region, T and P are not independent properties. If you specify T_{sat}, P_{sat} is also specified.

	T_{sat}, C	P_{sat}, kPa	P_{sat}, atm	
	20	2.339	0.0231	
Boiling point at 1 atm	100	101.325	1.00	
	200	1553.8	15.3	
Critical temperature	374.14	22090	218	Critical pressure

III. Evaluating Properties

3. A set of properties that completely describe a system specify the **state** of the system.
4. The State Postulate (an experimental observation)

The intensive state of a pure substance is completely specified by two independent, intensive properties.

a. for example, u = f(T,v). T and v (temperature and specific volume) are always independent, but T and P are not necessarily so. T and P are both intensive properties but in a two-phase region they cannot be varied independently.

b. independent means that one property can be varied while the other is held constant.

c. pure means that we have a single pure chemical species (dry air is considered pure).

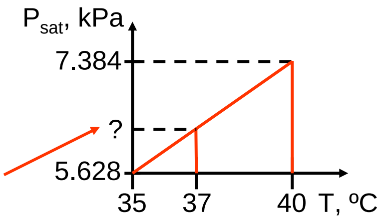
III. Evaluating Properties

5. Example - how high can you go with just a cylinder of oxygen on your back? In other words, how high can you go before your lungs fill with water vapor because the atmospheric pressure is so low?

Approach: The temperature of body is 37 C. We need the saturation pressure of water at this temperature. We can then find the altitude above the earth's surface at which the atmospheric pressure is equal the saturation pressure. If we exceed this altitude, the water in your lungs will boil and you will not be able to breath in oxygen.

- Find saturation pressure at 37 C. From Table A-4, p. 890

T_{sat}, C	P_{sat}, kPa
35	5.628
37	?
40	7.384

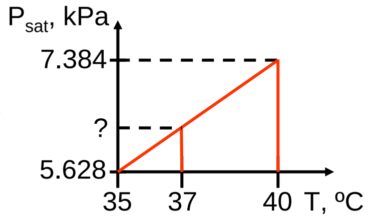


How do we get P_{sat} at 37 C?

III. Evaluating Properties

If we assume that P_{sat} varies linearly with temperature, we can linearly interpolate to find the pressure we need. Use similar triangles to give

$$\frac{P_{37}-P_{35}}{37-35}=\frac{P_{40}-P_{35}}{40-35}$$



Substituting the data from the table gives

$$\frac{P_{37}-5.628}{37-35}=\frac{7.384-5.628}{40-35}$$

Solving for the unknown pressure gives

$$P_{37}=5.628+\frac{7.384-5.628}{40-35}(37-35)=6.3304\ kPa$$

III. Evaluating Properties

- Find altitude at which the atmospheric pressure is 6.3304 kPa.

From p. 14-13 of 73rd ed. of CRC Handbook of Chemistry and Physics,

z, m	P_{atm}, kPa
19,000	6.4674
?	6.3304
20,000	5.5293

Interpolating linearly gives the altitude at which the lungs would fill with water vapor and it would be impossible to breath:

$$z = 19000 + \frac{20000 - 19000}{5.5293 - 6.4674}(6.3304 - 6.4674) = 19100\ m$$

The altitude of Mt. Everest is 8848 m.