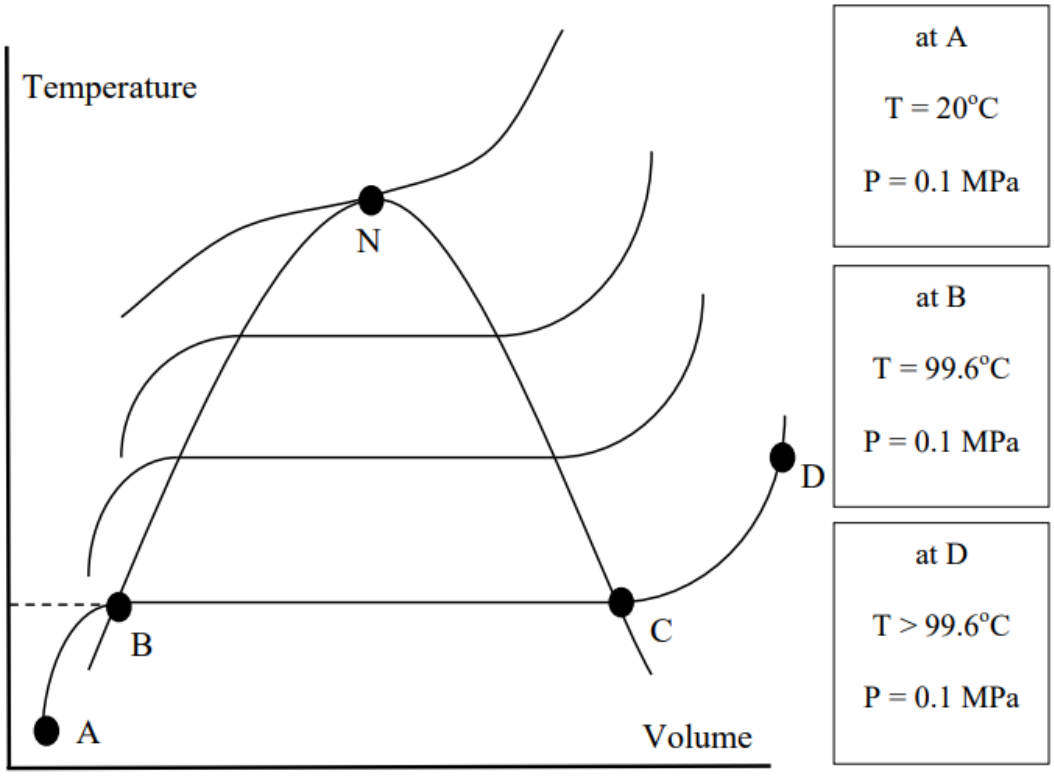
3.4 PROPERTY DIAGRAMS FOR PHASE-CHANGE PROCESSES

The variations of properties during phase-change processes are best studied and understood with the help of property diagrams. Next, we develop and discuss the T-v, P-v, and P-T diagrams for pure substances.

3.4.1 THE (T-V) DIAGRAM

Let us consider a temperature-volume (T-V) diagram for a heating process at constant pressure for a pure substance.



• Point A represents the initial state, point B is the saturation temperature at 0.1 MPa (99.6°C). Line AB represents a heating process with no change of phase.

• Point C is the saturated vapor state. Line BC is the constant temperature and pressure (change of phase; evaporation).

• Line CD represents the process during which the steam becomes superheated. During this process the temperature and specific volume increases and the pressure remains constant.

• Line ABCD represents a constant pressure line on the (T-V) diagram; i.e. heating process of constant pressure with change of phase.

Similar lines may be drawn for heating processes at other pressure values. At a pressure of (22.06 MPa), we find that there is no constant temperature vaporization process. Instead point (N) is a point of inflection with zero slop. This point is called the **critical point** which is the point where the **saturated vapor** and **liquid can coexist**. At the critical point the temperature, pressure and specific volume are called **critical temperature**, **critical pressure** and **critical specific volume**. The line joining the saturated liquid temperatures is called the saturated liquid line, and the line joining the saturated vapor temperatures is called the saturated vapor line as illustrate in Figure (3.2).

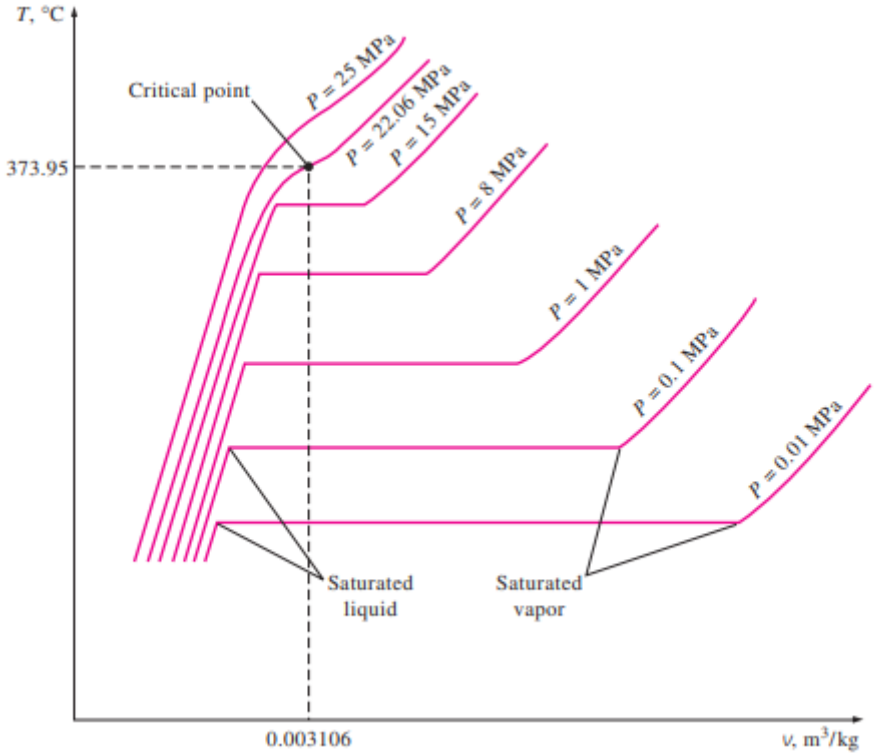
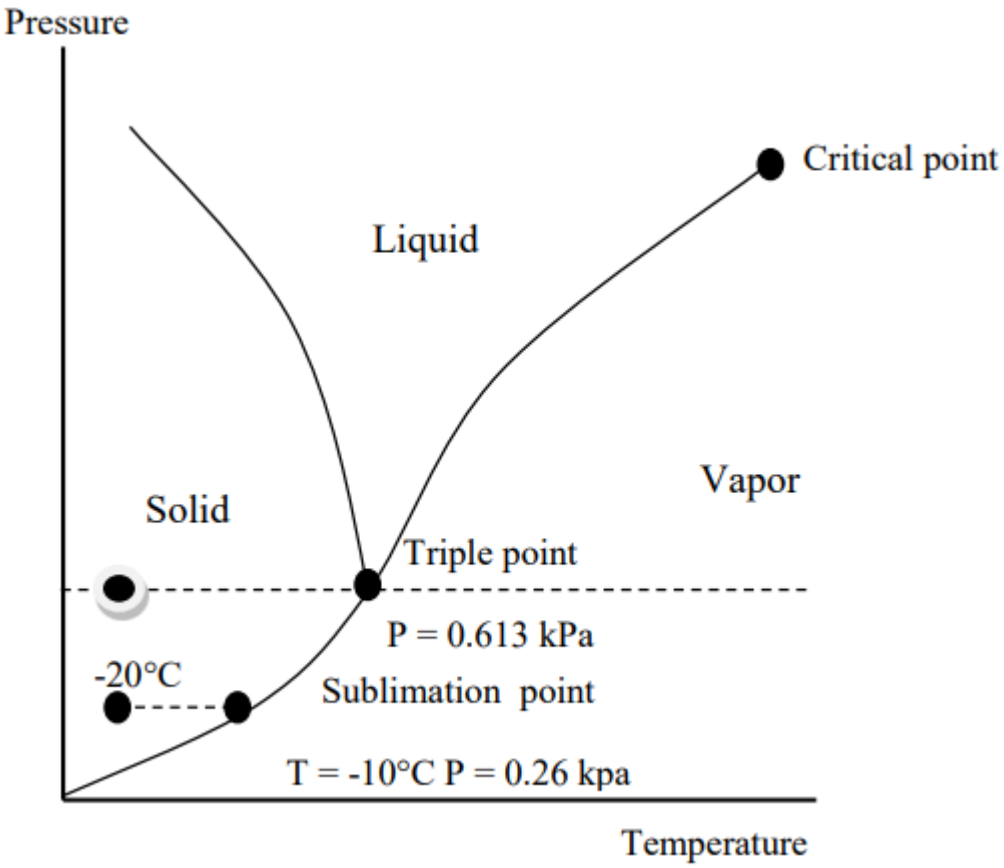


Figure (3.2) T-v diagram of constant-pressure phase-change processes of a pure substance at various pressures (numerical values are for water).

3.4.2 THE (P-T) DIAGRAM

Assume that a system consisting of (1 kg) of ice at (-20 °C) and (100 kPa) is contained in a piston-cylinder arrangement as in the previous example. When the system is **heated** the **pressure** remains **constant**. The **specific volume increases** slightly and it reaches (0 °C). At this point the ice melts while the temperature remains constant and in this state the ice is called **saturated solid**. When all the ice melts, any **further heating** results in an **increase** in the **temperature** of the **liquid**. Let the initial state of the ice be (-20 °C) and (0.26 kPa). The heating would result in increasing the temperature until (-10

°C). At this point the ice would pass directly from solid phase to vapor phase in a process known as **Sublimation**. Any further heating results in superheating the vapor.



When the initial state of the system is (-20 °C) and (0.613 kPa), the heating process results in increasing the temperature until it reaches (0.01 °C). Further heating may result in some of the ice becoming vapor and some becoming liquid. Therefore at these conditions it is possible to have three phases in equilibrium. This point is called **triple point**; which is **defined as the state in which the three phases of a pure substance may be present in equilibrium**.

When the **heating** process is carried out at a **pressure higher** than the triple point pressure, the substance would pass from **solid** phase to **liquid** phase and then from liquid phase to **vapor** phase at **higher temperature**.

3.4.3 THE P-v DIAGRAM

The general shape of the P-v diagram of a pure substance is very much like the T-v diagram, but the T = constant lines on this diagram have a downward trend, as shown in Figgure (3.3).

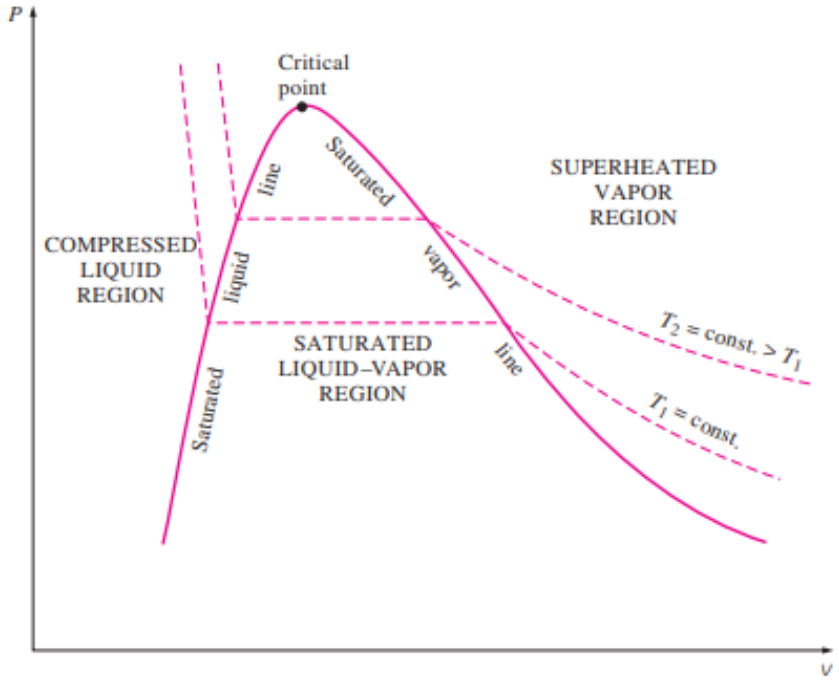


Figure (3.3) P-v diagram of a pure substance.

HOME WORK (3)

1- Define
   a- subcooled liquid
   b- compressed liquid
   c- quality
   d- superheated vapor
2- write the condition of the
   a- subcooled liquid.
   b- compressed liquid.
   c- superheated vapor.
3- sketch
   a- T-v diagram of constant pressure.
   b- P-v diagram of constant temperature.