Properties of pure Substance

Pure substance:- A pure substance is a substance of constant chemical composition throughout in mass. It is one component system. Water, nitrogen, hedium, carbon dioxide etc are example of pure substance.

A mixture of various chemical elements or compounds also qualifies as a pure substance as long as mixture chemical composition is constant throughout the mass. eg. Air. A mixture of ice and water also comes under pure substance since their chemical composition are same. It means pure substance may have mixture of two or more than also.

phases of pure substance

There are three principle phases, solid, liquid and gases - a substance may have several phases within the principles phases, each with different molecular structure eg Carbon may be exist as a graphite in solid phase.

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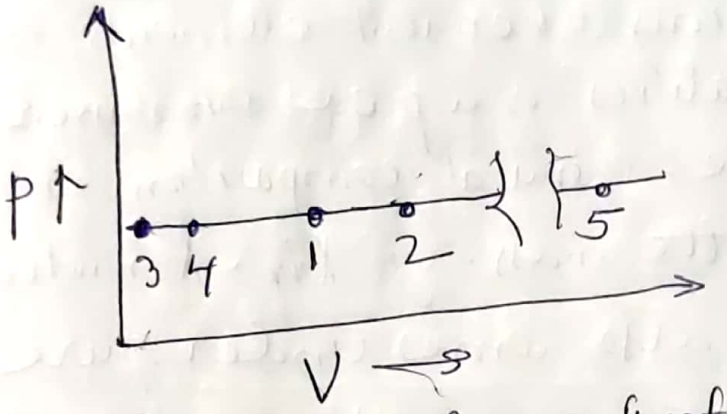
solid — intermolecular bond is strong

liquid — intermediate

gases — weaker intermolecular ~~bod~~ bond

P-V diagram of pure substance



Heating of H_2O (water) at constant pressure.

1-2 → Heating of ice (-10°C to 0°C) temperature and volume both increases

2-3 → Ice melts into water ~~at~~ constant constant temperature (at 0°C). This is called latent heat of fusion. At 3 process ends. In this process volume decreases. It is peculiarity of water

3-4 → Temperature increases from 0°C to 100°C. Volume increases due to thermal expansion.

(Note:- The internal energy associated with the phase of system is called latent heat)

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4-5 → At 100°C, water changes into vapour (latent heat of vapourisation) - large volume change occur

5-6 → Vapour heated - Volume and temperature increases

Between 1-2 → water exist in solid state

3-4 → liquid phase

beyond 5 → vapour phase

States 1, 2, 3, 4 and 5 are known as saturation state. A saturation state is a state from which a change of phase may occur without change of pressure or temperature.

State 2 → solid state because solid can change in liquid and at constant p and T.

State 3 & state 4 → liquid state. In state 3, the liquid is saturated with respect to solidification whereas in state 4, the liquid is saturated with respect to vapourization.

State 5 - saturated vapour state - vapour is saturated with respect to liquid state at constant temperature or pressure.

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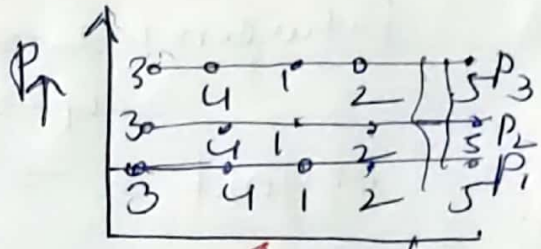
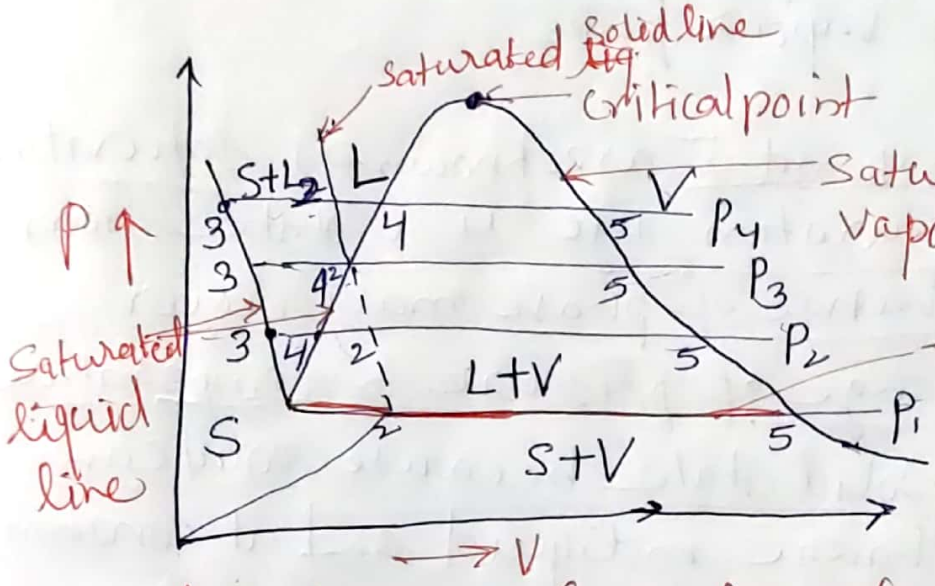
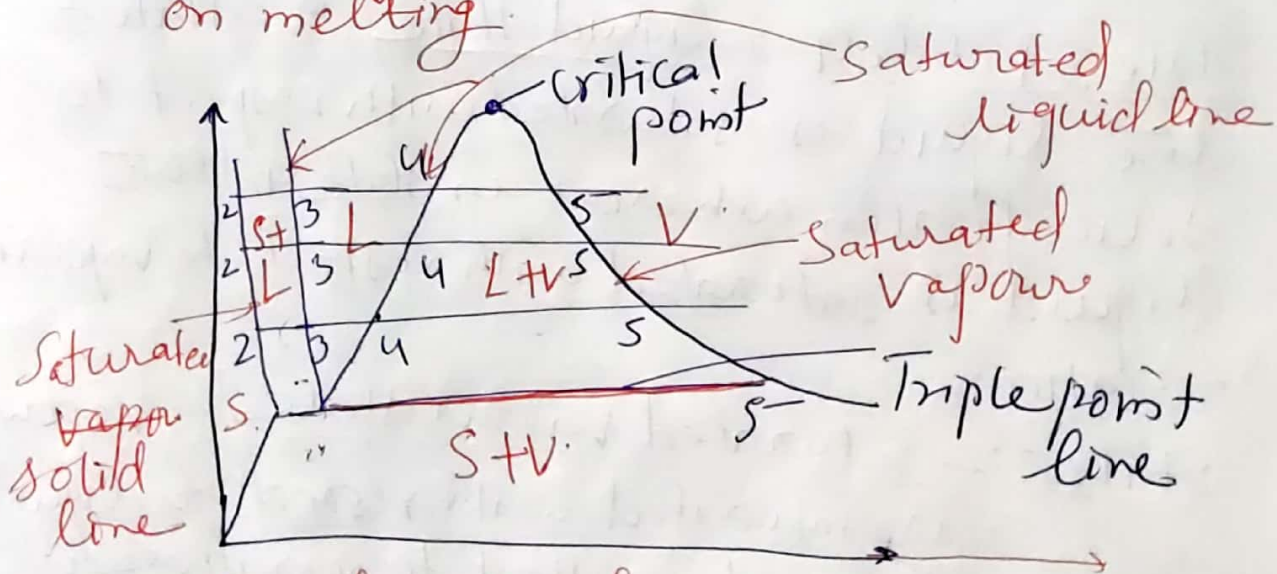
If heating of ice at -10°C to steam at 250°C were done at constant pressure P_2 similar regimes of heating would have been obtained with respect to the above stated. If similar saturation state, we will get like



(Change of volume of water at constant P)



P-V-diagram for water, whose volume decreases on melting



P-V diagram of pure substance other than water, where volume increases on melting.

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Triple point is a line on the PV diagram where all the three phases solid, liquid and gases exist in equilibrium. At pressure below triple point line, the substance can not exist in liquid form. Solid directly transform in vapour form (Sublimation).

Critical point Below the critical point only there is a liquid vapour transition zone where saturated liquid on heating absorbs the latent heat of vapourisation and becomes saturated vapour, on cooling, releases the latent heat of condensation at constant temperature and pressure to become saturated liquid. Above critical point, however, a liquid upon heating suddenly flashes into vapour or vice versa upon cooling. There is no distinct transition zone. The corresponding temperature, pressure & volume at critical point is called critical temperature, critical pressure & critical volume (for water $t_c = 374.15°C$, $P_c = 221.2$ bar, $v_c = 0.00317 m^3/kg$)

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Compressed liquids (subcooled liquid) and Saturated liquid

A piston cylinder device containing water at constant pressure and temperature say T_1 (temperature below vapourisation temperature). At this temperature and pressure, water is in liquid state. And as the temperature increases at constant pressure, water remains in liquid state, till the temperature rises upto vapourisation temperature. Upto this temperature and pressure, water is called compressed liquids or subcooled liquid. As the temperature reaches to vapourisation temperature, water starts to change its phase from liquid to vapour. A liquid which about to vapourise is called Saturated liquid.

In another words, If substance exist as a liquid at the saturation temperature and pressure, it is called saturated liquid. If the temperature of the liquid is lower than saturation temperature at given pressure, it is called subcooled or compressed liquids.

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Saturated and superheated vapours

If a substance exist as a vapour at the saturation temperature and pressure it is called saturated vapour. In other words, a vapour that is about to condense is called saturated vapour. Therefore, state 4 shown in PV diagram is saturated vapour state. If the temperature of vapour is greater than the temperature of the saturation (saturation temperature) of the vapours at given pressure it is called superheated vapour. The temperature and pressure are independent properties in this case.

Saturation temperature and Saturation pressure

Phase changes occurs at constant pressure and temperature. A pure liquid at given pressure will transform into vapour only at particular temperature called saturation temperature (which is function of pressure) Similarly for saturation pressure temperature remains constant.

At a given pressure, the temperature at which a pure substances changes

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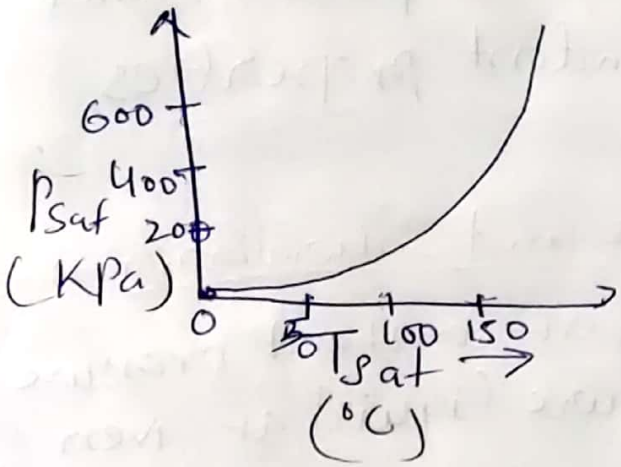
its phase is called saturation temperature (T_{sat}). Likewise, at given temperature, the pressure at which pure substances changes phase is called the saturation pressure (P_{sat}). At pressure of 101.325 KPa, T_{sat} = 99.97°C, like that at temperature of 99.97°C, P_{sat} = 101.325 KPa for water.

For pure substances there is a definite relationship between saturation pressure and temperature. The higher the pressure, higher the saturation temperature.



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