1.1 Phase equilibrium

A phase is a homogenous physical state into which a substance can exist; for example, solid, liquid and vapor/gas

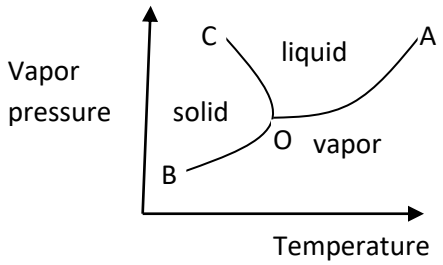
Factors affecting the phase of a substance

These include temperature and pressure. By varying temperature and pressure, it is possible to convert solid into a liquid or gas and the vice versa or a liquid into a gas or a gas into a liquid.

A plot of vapor pressure against temperature of a substance in the liquid, gas or solid state yield graphs called **phase diagrams**.

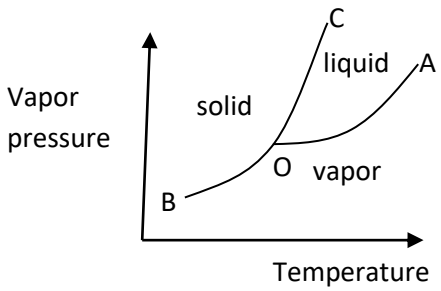
There are three forms of phase diagrams:

(a) Form A is shown by a substance such as water which is accompanied with a decrease in volume when they melt or accompanied with increase in volume when they solidify.



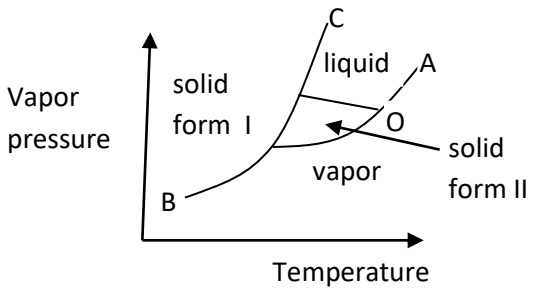
Form A

(b) Form B is shown by a substance such as benzene that is accompanied with an increase in volume when they melt



Form B

(c) Phase diagram form C is shown by a substance such as sulphur that exists in different solid form (allotropy)



Form C

At point O, all the three phases are in equilibrium and is called *triple point*. I.e. *triple point* is a point of temperature and pressure at which all the three phases (solid, liquid and vapor) are in equilibrium. The temperature and pressure corresponding to the triple point are triple point temperature and triple point pressure respectively.

The triple point temperature Tt^0C and pressure (Pt) for water and carbon dioxide are given below

Substances	Tt^0C	Pt
Water	0.0098	0.0060
Carbon dioxide	-56.1	5.0

With further rise in temperature the curve OA is obtained and this represents the conditions of temperature and pressure under which the liquid and vapor are in equilibrium.

This curve ceases at A and beyond this point the liquid and vapor are indistinguishable. This point is called the *critical point* and the corresponding temperature and pressure are called critical temperature (Tc^0C) and critical pressure (Pc) respectively.

Example	Tc^0C	Pc
Water	374	218
CO_2	37	72.8

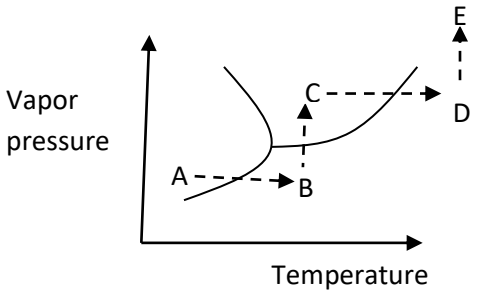
OB represents conditions of temperature and pressure at which solid and vapor are in equilibrium.

OC represents conditions of temperature and pressure at which liquid and solid are in equilibrium

Exercise

Trial 1

The phase diagram of a certain pure substance is given below

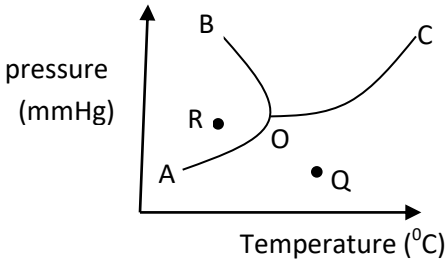


Describe the changes in temperature, pressure and phase if any, in each of the following steps in the diagram above.

(i) A to B
(ii) B to C
(iii) C to D
(iv) D to E

Trial 2

The diagram below shows the variation of vapor with temperature for pure substance.



(a)(i) On the diagram, indicate the different phases of the substance (1½mk)

(ii) State what happens at point O (1mk)

(b) High pressure was applied at constant temperature to the phase at point Q. Describe the changes that took place

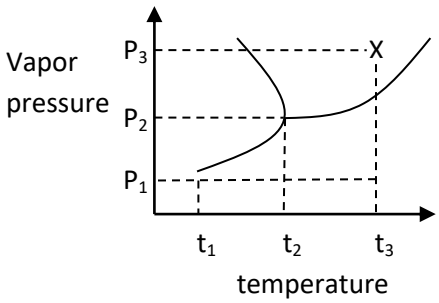
(1½mk)

(c) The temperature at point R was increased at constant pressure. state what was observed

(1mk)

Trial 3

The figure shows the phase diagram for water.



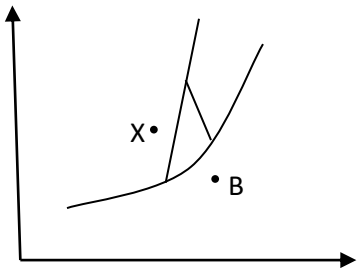
(i) State the phase that exist at temperature t_2 and P_2 (1½mk)

(ii) What happens to the phase in (i) when pressure is kept constant but temperature is changed from t_2 to t_1 (1½mk)

(iii) State what would happen to phase at X if pressure is changed from P_3 to P_1 at temperature t_3 (1mk)

Trial 4

Fir.2 is a phase diagram for a certain substance.



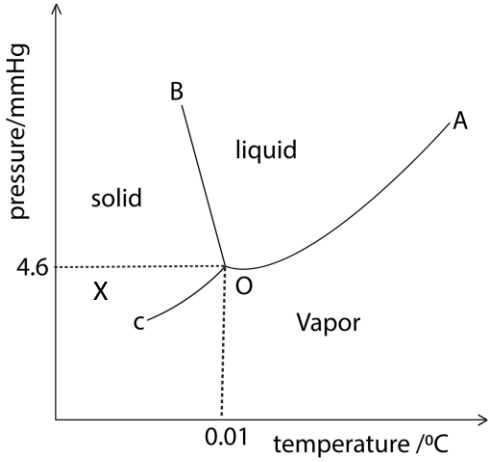
(a) Label the following on the diagram
  (i) the axes
  (ii) the phases
  (iii) critical temperature, t
  (iv) the triple point, O

(b) Define the terms
  (i) critical point
  (ii) triple point

(c) Explain what would happen when the substance in point X changes to point B

Trial 5

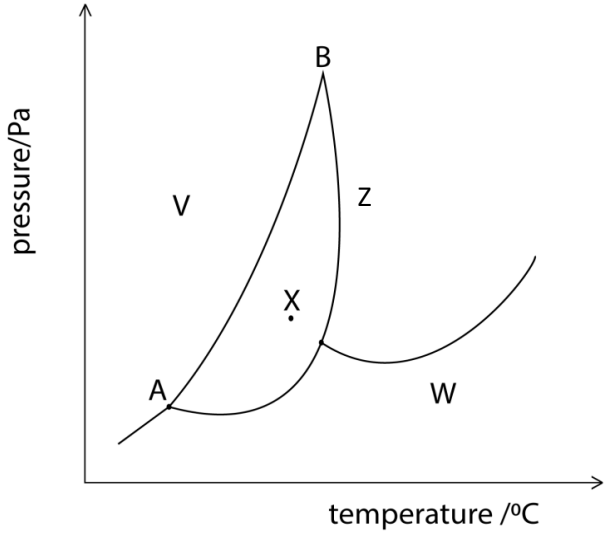
The phase diagram of water is shown below



(a) State what the following points represent., A and O.
(b) State what would happen if ice at point X is heated at constant pressure
(c) From the diagram, state one condition necessary for ice to melt.

Trial 6

The phase diagram of substance E is shown below



(a) Identity the phase at W, V, Z
(b) Name curve AB
(c) State what would happen to the phase of E at x when pressure is lowered at constant temperature
(d) State how you would expect the melting point of E to vary with increase in pressure?

Suggested answers

Trial 1

(i) Pressure remain constant, the temperature is increase, solid at A changes to vapor at B.

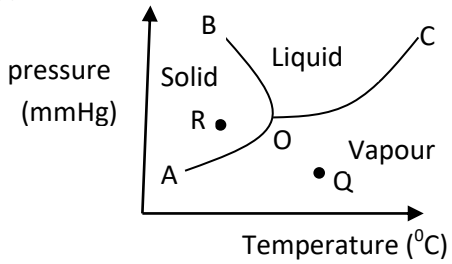
(ii) Pressure increases, temperature remains constant, vapor at B changes to Liquid at C

(iii) Pressure remain constant, the temperature is increase, Liquid at C changes to vapor at D.

(iv) Pressure increases, temperature remains constant, vapor remains unchanged.

Trial 2

(a)(i)



(ii) solid, liquid and vapour at equilibrium

(b) changes from vapor to liquid

(c) solid turns to vapor (sublimes)

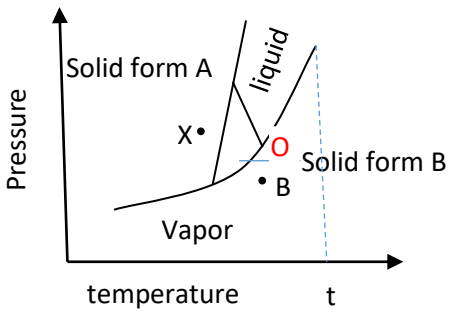
Trial 3

(i) Solid, liquid and vapor

(ii) Vapor and liquid turn into solid

(iii) Liquid turns into vapour

Trial 4



(b) (i) Critical point is temperature and pressure beyond which liquid and vapor are indistinguishable

(ii) Triple point is temperature and pressure at which liquid, solid and vapour are in equilibrium

(d) When temperature is increased and pressure decreased, solid form A changes to solid form B to vapor.

Trial 5

(a) Liquid, vapour and solid in equilibrium
(b) Turns into vapor
(c) High pressure, high temperature

Trial 6

(a) W – vapour
V – solid
Z is liquid
(b) Transition curve
(c) Solid turns into vapor
(d) Melting point increases with pressure