Eutectic mixtures

These are mixtures which at constant pressure freeze at constant temperature to give a solid of the same composition.

Similarities between eutectic mixture and pure compound

a) both have a sharp freezing point at constant pressure
b) Have the same composition in liquid and liquid

Reasons why eutectic mixtures are not compound

a) their composition varies with pressure
b) can be separated by other physical methods as distillation and evaporation to dryness
c) X-ray analysis shows that eutectic mixtures are not pure compound
d) Microscopic analysis shows that eutectic mixtures are heterogeneous, made of a mixture crystals of separate substances
e) Chemical properties of eutectic mixtures are those of individual components making up the mixture for example when solder is reacted with dilute hydrochloric acid, tin reacts whereas lead does not.

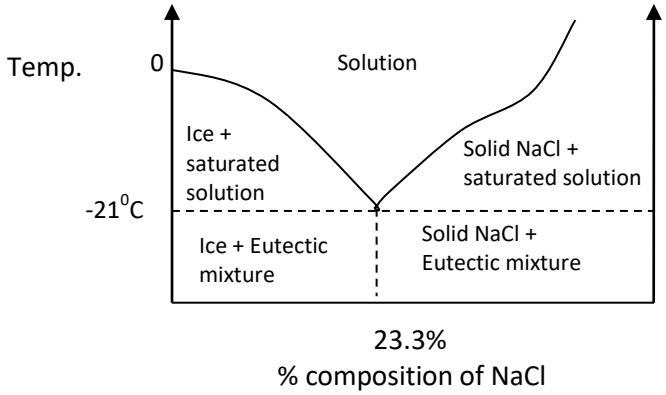
Conditions necessary for formation of eutectic mixtures

- pure crystals of the components should separate from mixture on cooling.
- The two substance involved must be completely miscible when melted

Consider a solution of NaCl in water; when a solution containing less than 23.3% NaCl is cooled, pure crystals of Ice will separate out at a temperature below 0^0C. As this occurs the solution become richer in NaCl leading to further depression of the freezing point until about -21 ^{0}C. At this temperature the composition of the solution is 23.3% NaCl and further cooling temperature remains constant until both sodium chloride and water have frozen together to form a solid of the same composition.

Alternatively; when a solution containing more than 23.3% of sodium chloride is cooled, NaCl separate out as temperature falls until the concentration of the solution is about 23% and this occurs at about -21^0C. Here water and NaCl freeze to form a solid of the same composition.

Graphically, the above information can be represented on eutectic diagram below



The mixture of salt and ice which crystallizes at -21^{0}C from either a dilute or concentrated solution is called eutectic mixture and the temperature at which the mixture freezes is called Eutectic temperature.

Other substances that can form eutectic mixtures are

(i) Tin (mpt. 232) and lead (mpt.227); Eutectic composition is 66% Pb and eutectic temperature 183^{0}C.

(ii) Zinc (mpt. 491) and cadmium (mpt. 321^{0}C); eutectic composition 75% Zn and temperature 270^{0}C.

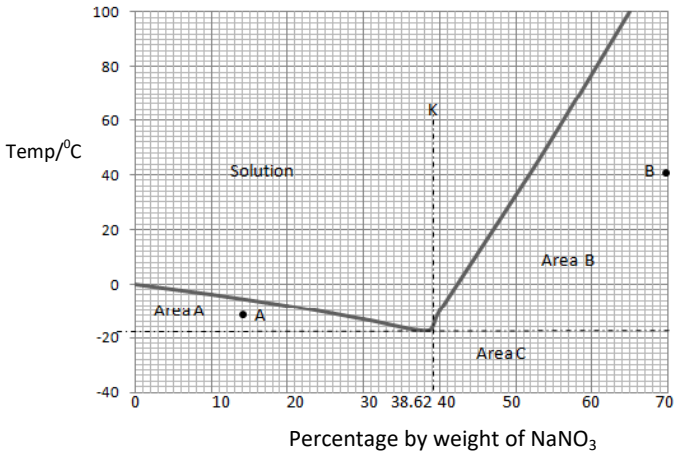
Example 1

a) Explain the following term

(i) solubility (3marks)

(ii) Eutectic mixture (3marks)

b) The equilibrium diagram for the sodium nitrate-water system is shown below



(i) State what lines DE and EF represent (2mk)

DE- freezing/melting point of solutions containing less than 38.62% sodium nitrate

EF – solubility curve for solutions containing more than 38.62% sodium nitrate at various temperatures

(ii) Determine the % of sodium nitrate at points A, B and C (3mks)

A: 26% (draw a horizontal line to touch the curve and a vertical line to read the concentration)

B: 52%

C: 38.62%

(iii) Name the substances at A, B, and C (4½mk)

A: ice and sodium nitrate

B: solid $NaNO_3$ and solution

C: Eutectic + solid $NaNO_3$

(a) (i) What would be observed if a solution having the composition K was cooled slowly

The solution remains in liquid form until -17.5^0C; here the temperature remains constant until all the liquid has turned into a solid, and then the temperature of the solid falls.

(ii) State two reasons why eutectic mixtures are not compounds.

- they can be separated by other physical means such as evaporation to dryness
- their composition varies with pressure

Revision exercise

Trial 1

(a) Define the term eutectic mixture (3marks)

(b) The table below shows the melting points of various mixtures of tin and lead

%Tin	0	20	40	70	80	100
Mpt/^{0}C	327	280	234	193	206	232

(i) Draw a fully labeled diagram for the tin-lead system (5marks)

(ii) Determine the eutectic temperature and composition of the eutectic mixture (3marks)

(c) Describe the changes that would take place when a liquid mixture of the above system containing 40% tin is cooled from 400^{0}C to 100^{0}C (6marks)

(d) (i) state one application of the tin-lead eutectic mixture (1mark)

(ii) Name one other pair of metals which can give a similar phase diagram as in(b)(i)

(iii) State one similarity between a eutectic mixture and pure metal (1mark)

Trial 2

(a) Define the term eutectic temperature (1mk)

(b) the melting points of different composition of cadmium and zinc are shown in the table below

% of Zinc	0	10	17	30	60	100
Mpt/^{0}C	321	295	270	305	360	491

(i) Draw a well labeled melting point-composition diagram for cadmium-zinc mixture

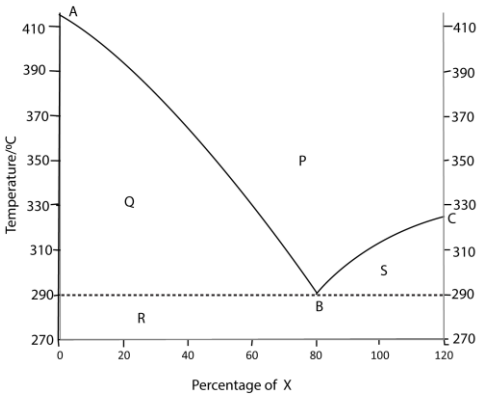
(ii) Explain phase changes which take place if a liquid mixture containing 5% zinc is cooled from 306 to 250^{0}C

(iii) 200g of the liquid mixture of composition 5% zinc was cooled to 275^{0}C. determine the composition of the remaining liquid mixture at 275^{0}C

(iv) Calculate the mass of cadmium in the remaining liquid mixture at this temperature.

(c) Mention three tests which can be carried out on an eutectic mixture to show that it is not pure compound (3marks)

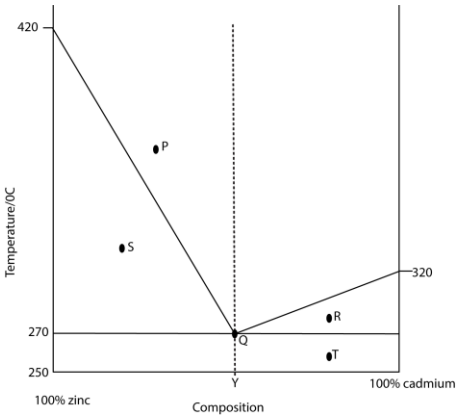
Trial 3 The phase diagram of a mixture of metals X and Y is shown below



(a) State how the above curve was obtained (02mark)
(b) Identify the regions P, Q, R and S. (02marks)
(c) State what point B represent
(d) Using the diagram estimate the melting points of X and Y. (01mark)
(e) Describe what would happen if a mixture containing 50% by mass X and Y is cooled from 410^0C to 270^0C. (03marms)

Trial 4

(a) Define the term eutectic mixture (1 ½ marks)
(b) The phase diagram for zinc-cadmium is shown below

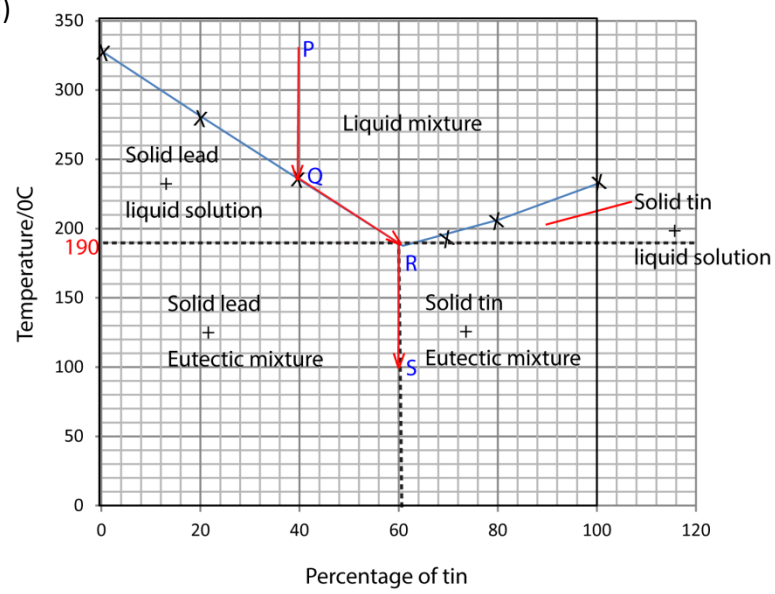


(i) State the phases at point P,Q, R, S and T. (2 ½ marks)
(ii) State what would be observed if a solution of composition Y was cooled slowly
(c) Give three reasons why eutectic mixtures are not compounds

Suggested answers

Trial 1

(b)(i)



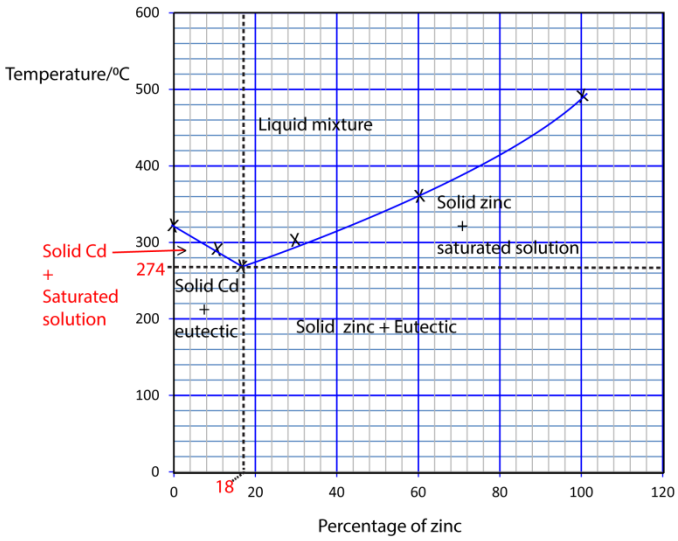
(b)(ii) Eutectic composition 60% tin,
Eutectic temperature 190^{0}C

(c) The temperature of the liquid falls from 400^{0}C to about 235^{0}C along PQ (shown on the graph); at Q solid lead crystallizes out and the freezing point of the remaining solution drops along QR as more lead solidifies. At R (190^{0}C) the composition of tin will be 60%, temperature remains constant until all the liquid has turned into a solid before the temperature drops further to 100^{0}C along RS.

(d) (i) welding
(ii) Zn and Cd, Cu and Zn, Ca and Mg,
Pb +Ag
(iii) both have a sharp melting point
Have same cooling curve
Have the same composition in solid as in liquid

Trial 2

(b)(i)



(ii) The mixture remains a liquid up to about 306^{0}C, at which pure solid cadmium starts to crystallize out. The freezing point of the liquid mixture drops to 274^{0}C as more pure cadmium solid is removed. At 274^{0}C, the composition of zinc becomes 18% Zinc (eutectic composition). The temperature remains constant until all the liquid turns into a solid and finally the temperature of the solid drops to 250^{0}C.

(iii) it is 18% zinc and 82% cadmium

(iv) Let the mass of cadmium that crystallize out be X

$$\frac{190 - X}{200 - X} = \frac{82}{100}$$

X = 14.3

Total mass of liquid mixture at 275^{0}C

200 -14.3 = 185.7

then mass of cadmium = $\frac{82}{100}\ x\ 185.7 = 152.3$

(c) test whether composition changes with pressure

- whether on distillation components separate
- whether using solvent extraction the components separate
- whether using chromatography components separate.
- Microscopic examination show that eutectic mixture is a mixture of crystals of separate pure compounds
- properties of eutectic mixture is the sum of the properties of individual components

Trial 3

(a) by determining the freezing points of various mixtures of x and Y.

(b) P- liquid mixture
Q – solid Y + liquid mixture
R – solid Y + eutectic mixture
S – solid X + liquid mixture

(c) B – eutectic point or temperature and pressure at which eutectic solidify.

(d) X = 320^0C; Y = 420^0C

(e) – the mixture freezes at 346^0C.
- Solid Y crystalizes out
- Freezing point of solution falls to 290^0C as the composition of X increases to 80%
- At 290^0C, the temperature remains constant as both A and Y solidifies together to form a solid of constant composition.
- The temperature of the solid falls to 270^0C

Trial 4

(a) P – Liquid mixture
Q- solid and liquid mixture at equilibrium
R – solid cadmium and liquid mixture
S – solid zinc and liquid mixture
T- solid cadmium and solid eutectic

(b) Solidifies at constant temperature to give a solid of constant composition
(c)

(i) their composition varies with pressure

(ii) can be separated by other physical methods as distillation and evaporation to dryness

(iii) X-ray analysis shows that eutectic mixtures are not pure compound

(iv) Microscopic analysis shows that eutectic mixtures are heterogeneous, made of a mixture crystals of separate substances

(v) Chemical properties of eutectic mixtures are those of individual components making up the mixture for example when solder is reacted with dilute hydrochloric acid, tin reacts whereas lead does not.