Microencapsulation

Dr. Pawar Anil R
Asso. Prof.
MESCOP, Sonai

MICROENCAPSULATION

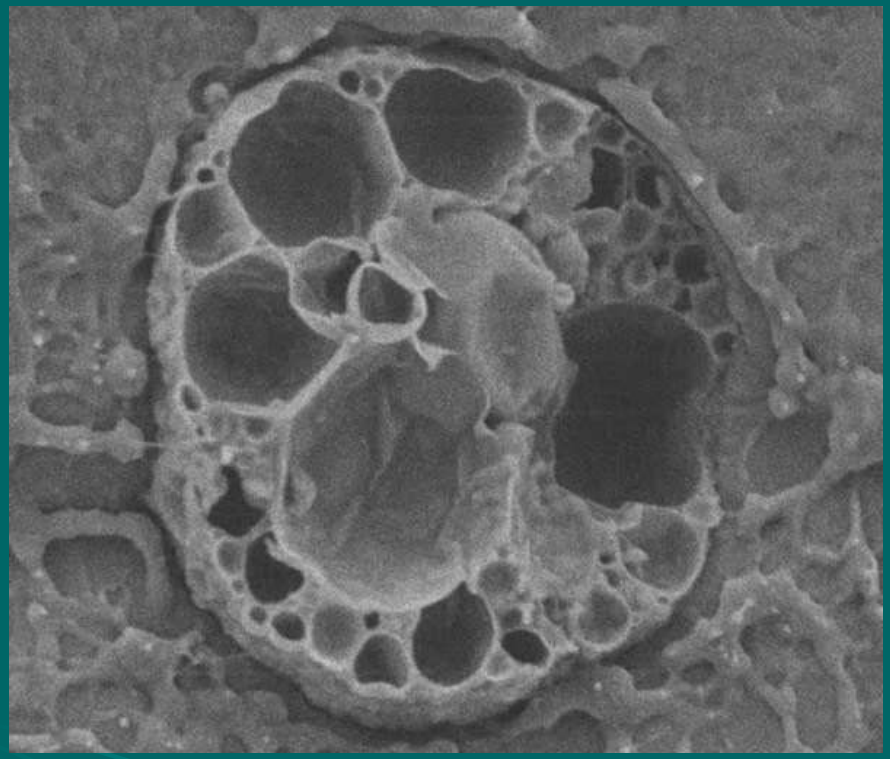
Microencapsulation is a means of applying thin uniform coatings to microparticles of solids dispersion or droplets of liquids.

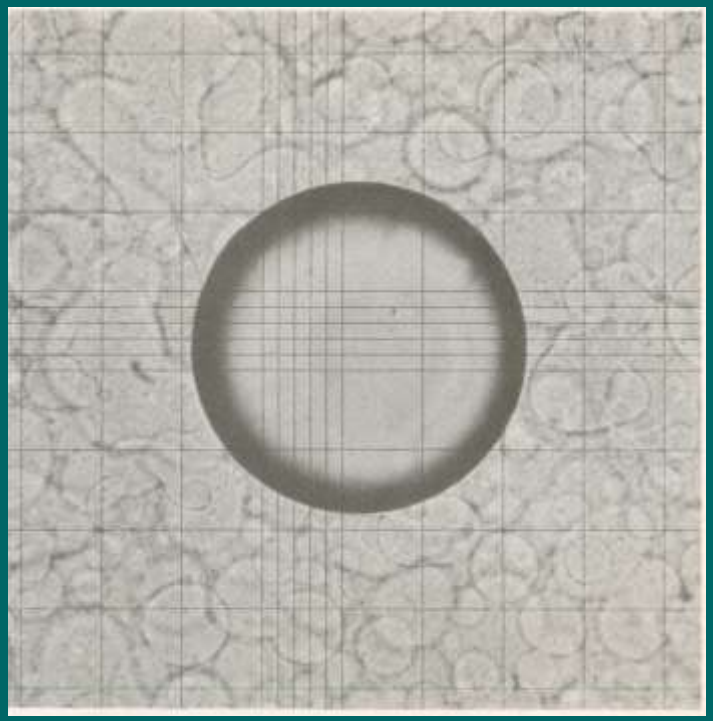
MICROCAPSULES

- Microcapsules are small particles that contain an active agent (core material) surrounded by a shell or coating.
- Their diameters generally range from a few microns to a few millimetres.
- Microcapsules can have many different types and structures:

a) simple droplets of liquid core material surrounded by a spherical shell (Microcapsules)

b) irregularly-shaped particles containing small particles of solid core material dispersed in a continuous polymer shell matrix (microspheres).





- **Microencapsulated solid microspheres**

Microencapsulated liquid

Mechanisms for the release of encapsulated core materials:

- Disruption of the coating by pressure, shear, or abrasion forces.
- Enzymatic degradation of the coating where permeability changes.
- Diffusion or leaching of core materials.

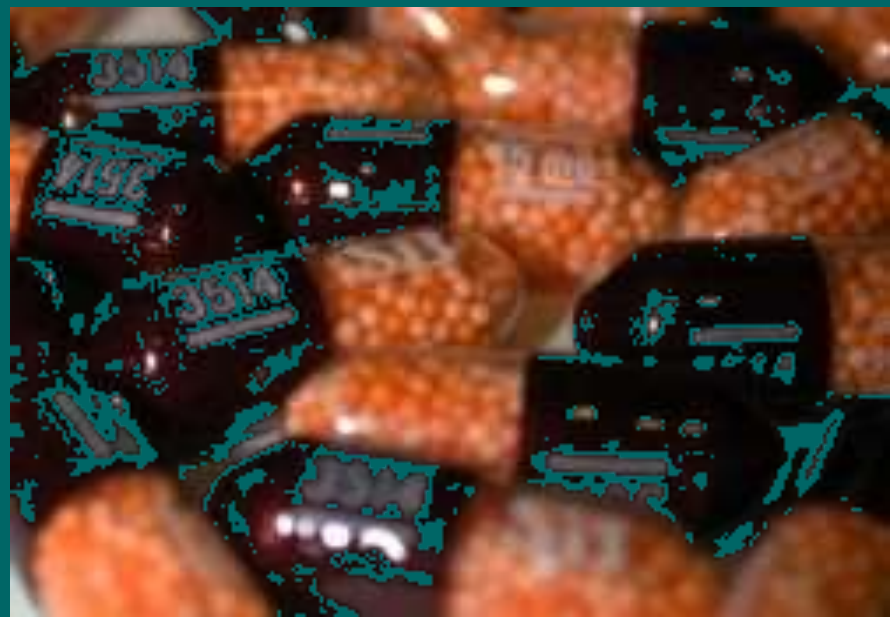
The rate of release of core material is a function of :

- the permeability of the coating to core material.
- the dissolution rate of the core materials
- the coating thickness
- the concentration gradient existing across the coating membrane.

APPLICATION OF MICROENCAPSULATION

Four important areas of microencapsulation application are :

1. The stabilization of core materials
2. The control of release or availability of core materials
3. Separation of chemically reactive ingredients within a tablet or powder mixture.
4. Taste-masking.



1.The stabilization of core materials

Examples:

Microencapsulation of certain vitamins to retard degradative losses.

Microcapsule stabilities of an anthelmintic (carbon tetrachloride), methyl salicylate, and flavors.

2. The control of release or availability of core materials

Controlled release from microencapsulated products are used for prolonged action or sustained-release formulations

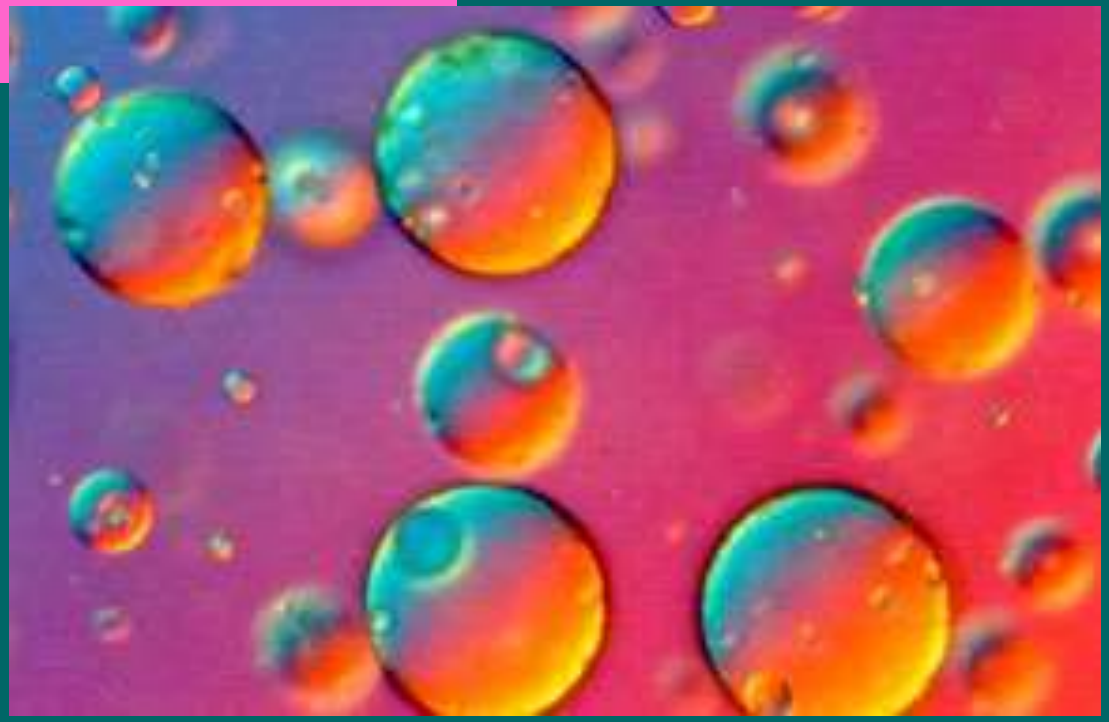
Example:

- The application of varied amounts of an ethyl cellulose coating to aspirin using coacervation phase-separation encapsulation techniques, where release of aspirin is accomplished by leaching or diffusion mechanism from the inert, pH-insensitive ethvl cellulose coating.

Some Microencapsulated Core Materials

Core Material	*Characteristic Property*	*Purpose of Encapsulation*	*Final Product Form*
Acetaminophen	Slightly water-Soluble solid	Taste-masking	Tablet
Aspirin	Slightly water-Soluble solid	Taste-masking; sustained release; reduced gastric irritation; separation of incompatibles	Tablet or capsule
Progesterone	Slightly water-soluble solid	Sustained release	Varied
Potassium chloride	Highly water-soluble solid	Reduced gastric irritation	Capsule

Microencapsules can be formulated as powders and suspensions, single-layer tablets, chewable tablets, creams, ointments, aerosols, dressings, plasters, suppositories, and injectables.



Core Material

- The core material is the material to be coated, which may be liquid or solid in nature.
- The composition of the core material can be varied:
- The liquid core can include dispersed and/or dissolved material.
- The solid core can be a mixture of active constituents, stabilizers, diluents, excipients , and release-rate retardants or accelerators.

Coating Materials

The coating material should:

- **Be capable of forming a film that is cohesive with the core material**
- **Be chemically compatible and non-reactive with the core material**
- **Provide the desired coating properties, such as strength, flexibility, impermeability, optical properties, and stability.**
- **Coating material selected from natural and synthetic film-forming polymers like:**

- carboxy methyl cellulose
- cellulose acetate phthalate
- gelatin, gelatin- gum arabic
- waxes
- ethyl cellulose
- poly vinyl alcohol
- poly hydroxy cellulose
- chitosan

MICROENCAPSULATION METHODS

1. Air suspension
2. Coacervation-phase separation
3. Spray drying
4. Congealing
5. Pan coating
6. Solvent evaporation techniques

Microencapsulation Processes and Their Applicabilities

Microencapsulation Process	*Applicable Core Material*	*Approximate Particle Size (μm)*
Air suspension	Solids	35-5000
Pan coating	Solids	600-5000
Multiorifice centrifugal	Solids & liquids	1-5000
Coacervation-phase separation	Solids & liquids	2-5000
Solvent evaporation	Solids & liquids	5-5000
Spray drying and congealing	Solids & liquids	600

Air Suspension

Microencapsulation by air suspension techniques **using**

Wurster Air Suspension Apparatus

A, control panel;

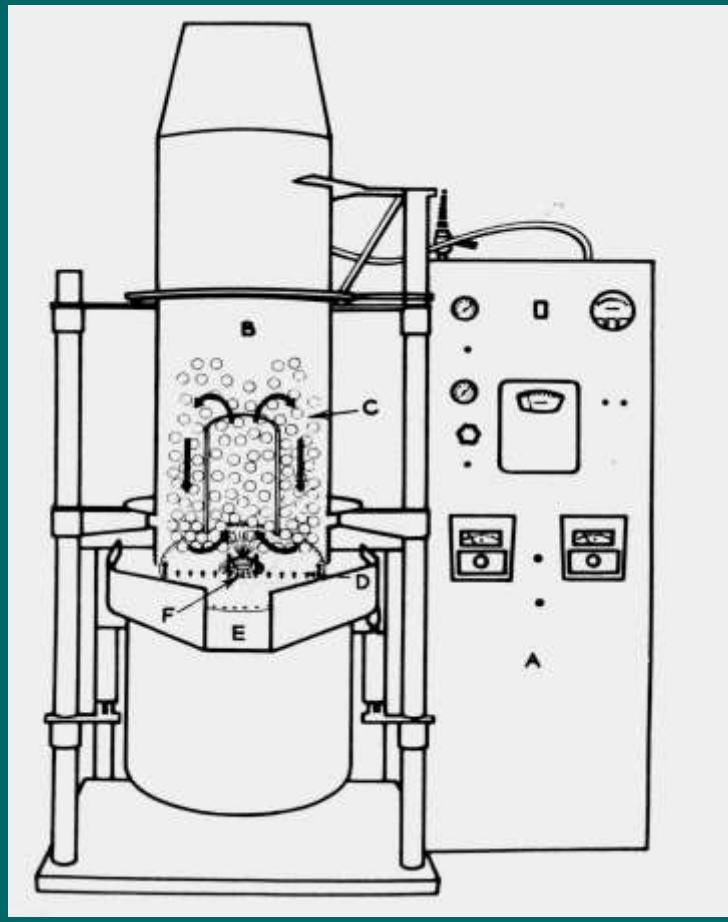
B, coating chamber;

C, particles being treated;

D, process airflow;

E, air distribution plate;

F, nozzle for applying film coatings.

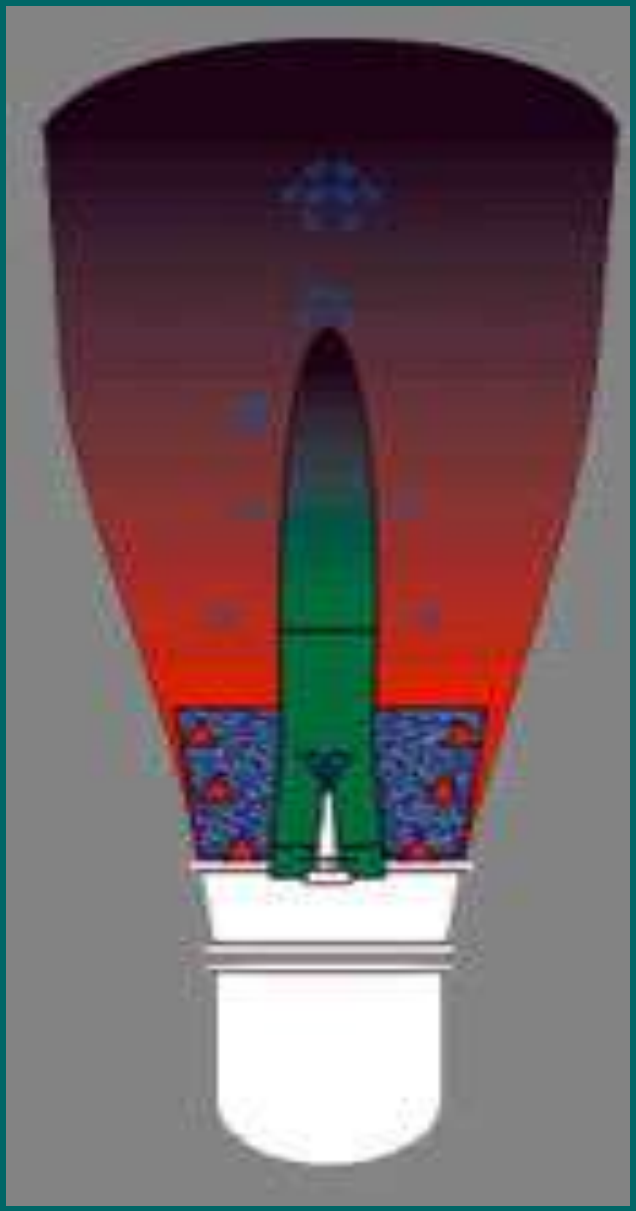


Schematic drawings of Wurster Air Suspension Apparatus

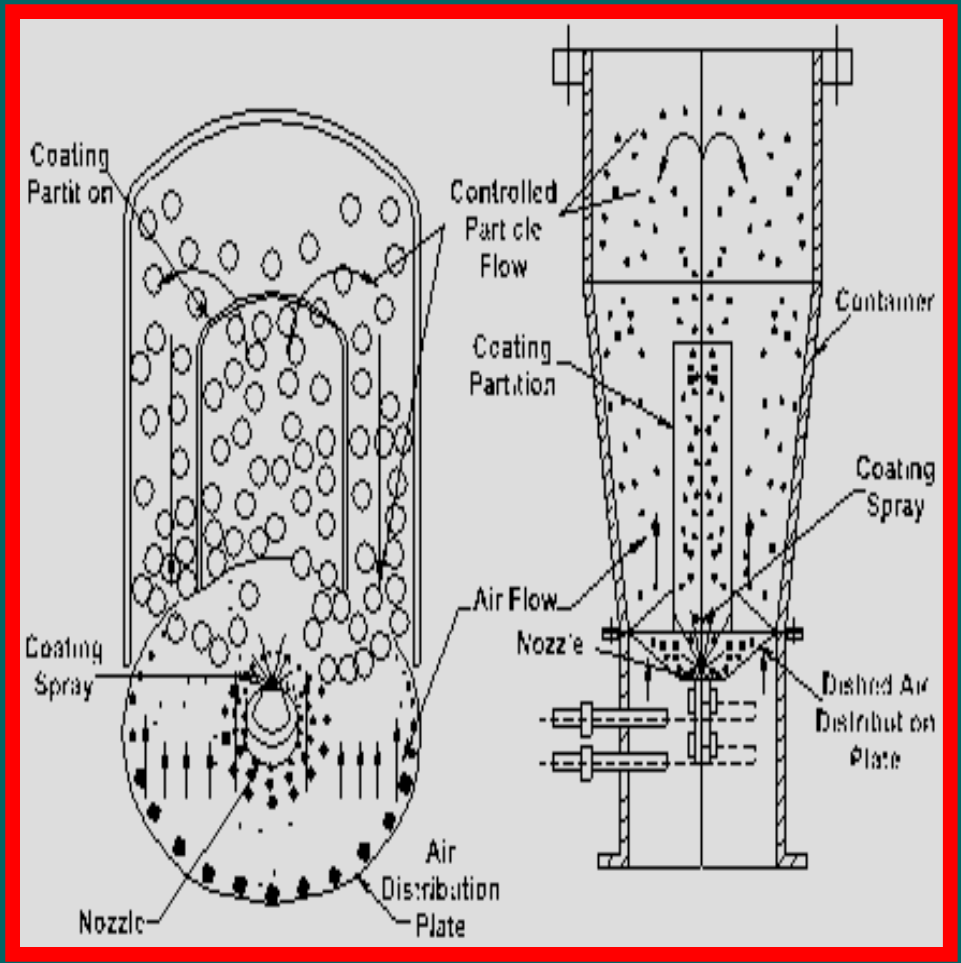
Principle

1. The Wurster process consists of the dispersing of solid particulate core materials in a supporting air stream and the spray-coating of the air suspended particles.
2. Within the coating chamber, particles are suspended on an upward moving air stream as indicated in the drawing.

3. The design of the chamber and its operating parameters provide a recirculating flow of the particles through the coating zone portion of the chamber, where a coating material, usually a polymer solution, is spray-applied to the moving particles.
4. During each pass through the coating zone, the core material receives an increment of coating material.



5. The cyclic process is repeated several times during processing, depending on the purpose of microencapsulation, the coating thickness desired.
6. The air stream also serves to dry the product while it is being encapsulated.

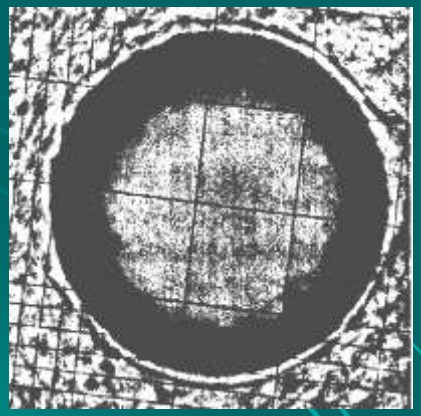


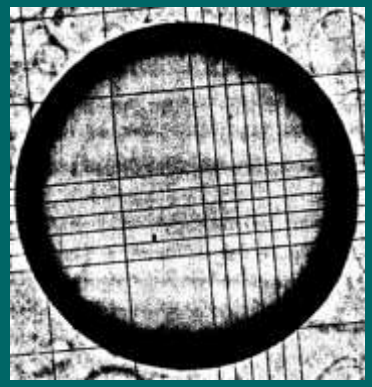
- The process has the capability of applying coatings in the form of solvent solutions, aqueous solutions, emulsions, dispersions, or hot melts
- The coating material selection appears to be limited only in that the coating must form a cohesive bond with the core material.
- The process generally is applicable only to the encapsulation of solid core materials
- Particle size, The air suspension technique is applicable to both microencapsulation and macroencapsulation coating processes with particle size range 35-5000 μm

Coacervation-Phase Separation

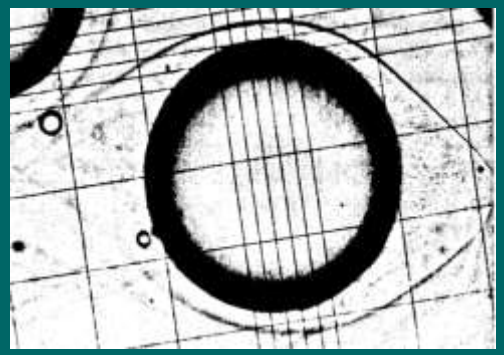
Coating formation during coacervation phase-separation process consists of three steps carried out under continuous agitation:

Step 1. formation of three immiscible chemical phases (vehicle ,Core and liquid coating).





Step 2. Deposition of liquid coating material.



Step 3. Rigidization of the coating

Step 1

Formation of three immiscible chemical phases:

A liquid manufacturing vehicle phase, a core material phase, and a coating material phase.

- To form the three phases, the core material is dispersed in a solution of the coating polymer, the solvent for the polymer being the liquid manufacturing vehicle phase.
- The coating material phase, an immiscible polymer in a liquid state, is formed by utilizing one of the methods of phase separationcoacervation:
  - by changing the temperature of the coating polymer solution
  - by adding a salt, nonsolvent, or incompatible polymer to the polymer solution; pH change;
  - by inducing a polymer-polymer interaction.

Step 2

Depositing the liquid polymer coating upon the core material.

- **This is accomplished by controlled, physical mixing of the coating material (while liquid) and the core material in the manufacturing vehicle.**
- **Deposition of the liquid polymer coating around the core material occurs if the polymer is adsorbed at the interface formed between the core material and the liquid vehicle phase, and this adsorption phenomenon is a prerequisite of coating.**
- **The continued deposition of the coating material is promoted by a reduction in the total free interfacial energy of the system, by the decrease of the coating material surface area during coalescence of the liquid polymer droplets.**

Step 3

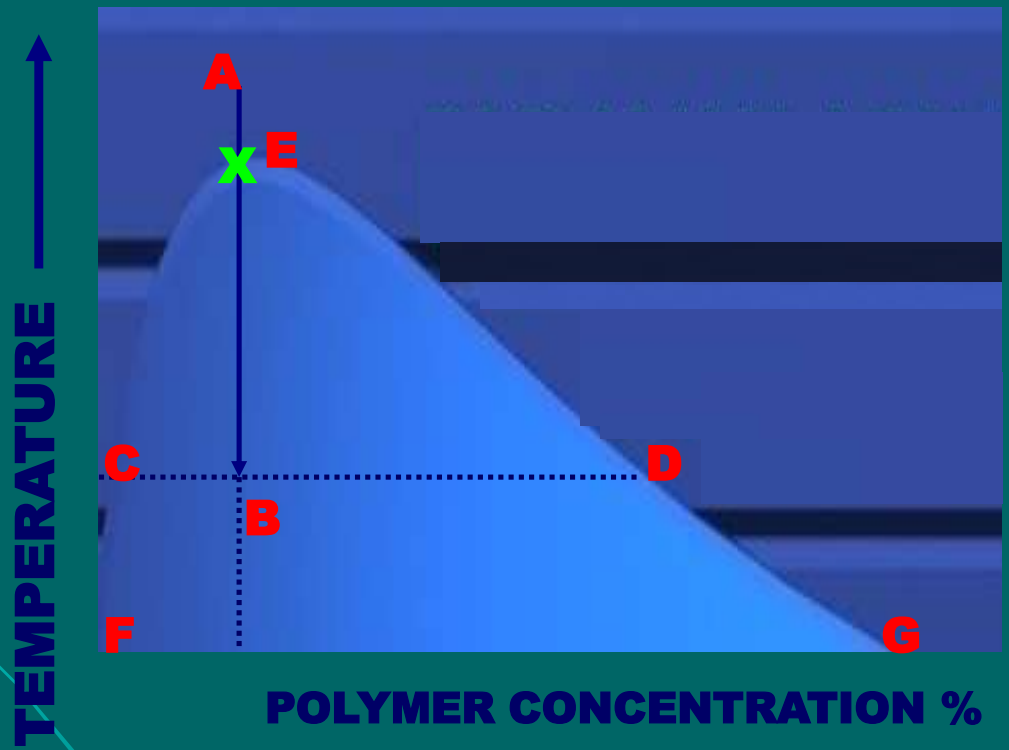
Rigidizing the coating,

By thermal , cross-linking (formaldehyde), or desolvation techniques, to form a self-sustaining ذاتيا مكتفية microcapsule.

Temperature Change

- Point X represent a system exists as a single-phase, homogeneous solution.
- As the temperature of the system is decreased (B) , Phase separation of the dissolved polymer occurs in the form of immiscible liquid droplets, and if a core material is present in the system, under proper polymer concentration, temperature, and agitation conditions, the liquid polymer droplets coalesce around the dispersed core material particles, thus forming the embryonic microcapsules.
- The phase-boundary curve indicates that with decreasing temperature, one phase becomes polymer-poor (the microencapsulation vehicle phase) and the second phase (the coating material phase) becomes polymer rich

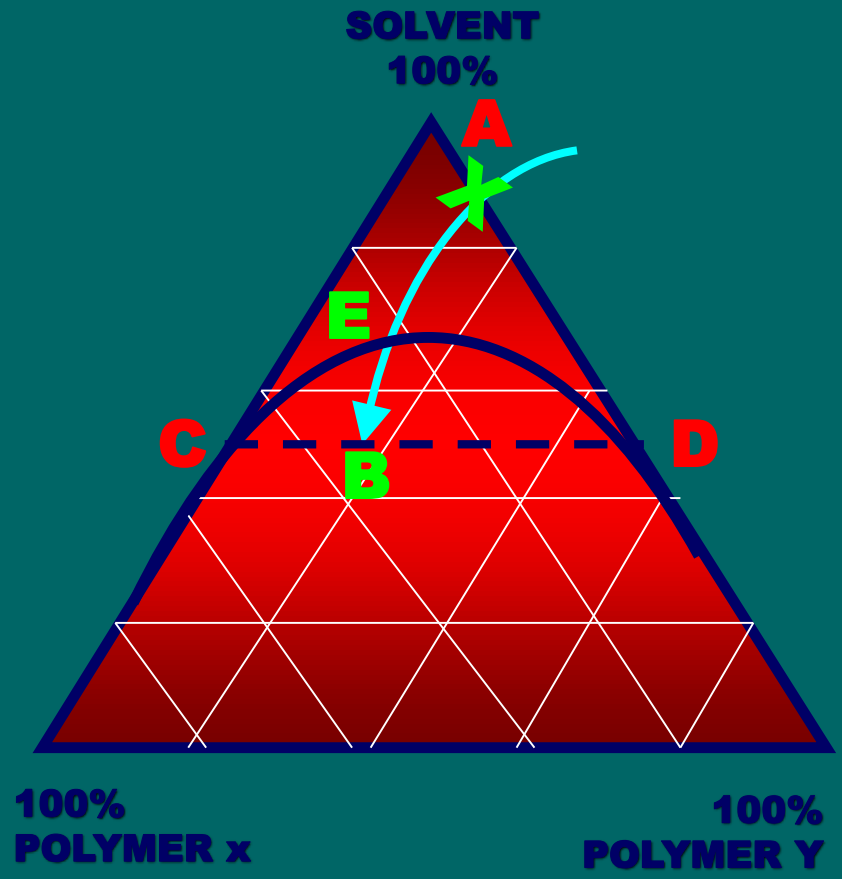
- The loss of solvent by the polymer-rich phase can lead to gelation of polymer, and hence rigidization or solidification of the microcapsule polymeric coating.



Temperature-composition phase diagram for a binary system of a polymer and a solvent.

Incompatible Polymer Addition

- The diagram illustrates a ternary system consisting of a solvent, and two polymers, X and Y.
- If an immiscible core material Polymer X is dispersed in a solution of polymer Y (point A) , the phase boundary will be crossed at point E.



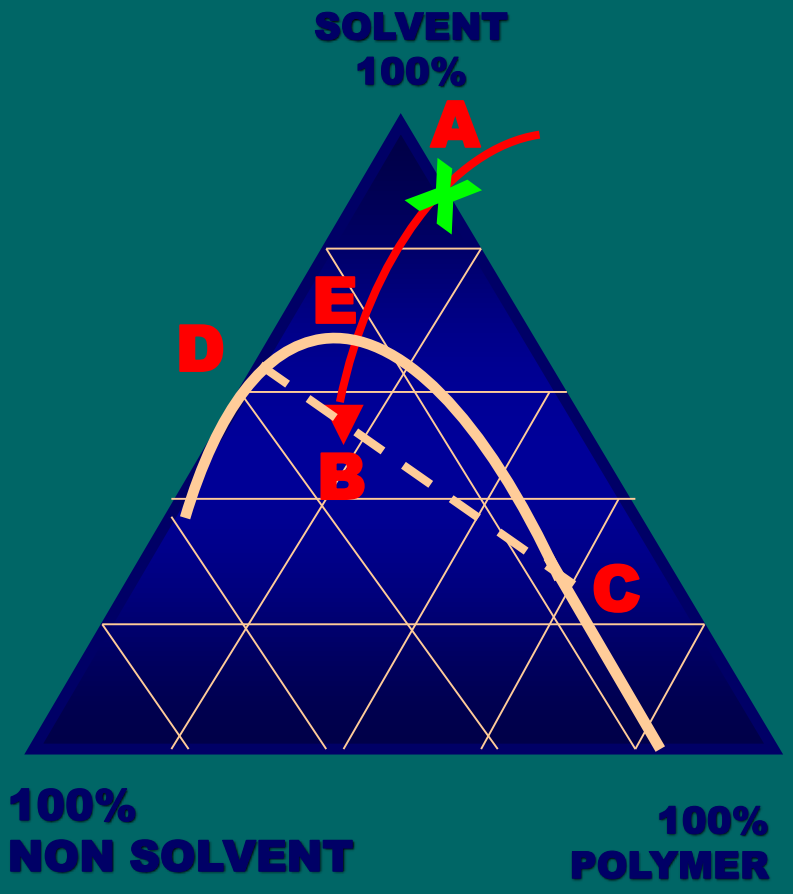
Phase diagram for phase-separation/ coacervation induced by Incompatible Polymer Addition

- As the two-phase region is penetrated with the further addition of polymer X, liquid polymer, immiscible droplets form and coalesce to form microcapsules.
- The polymer that is more strongly adsorbed at the core material-solvent interface, (in this case polymer Y), becomes the coating material.
- Solidification of the coating material is accomplished by further penetration into the two-phase region, washing the embryonic microcapsules with a liquid that is a nonsolvent for the coating, polymer Y, and that is a solvent for polymer X.

Nonsolvent Addition

A liquid that is a non-solvent for a given polymer can be added to a solution of the polymer to induce phase separation, as indicated by the general phase diagram.

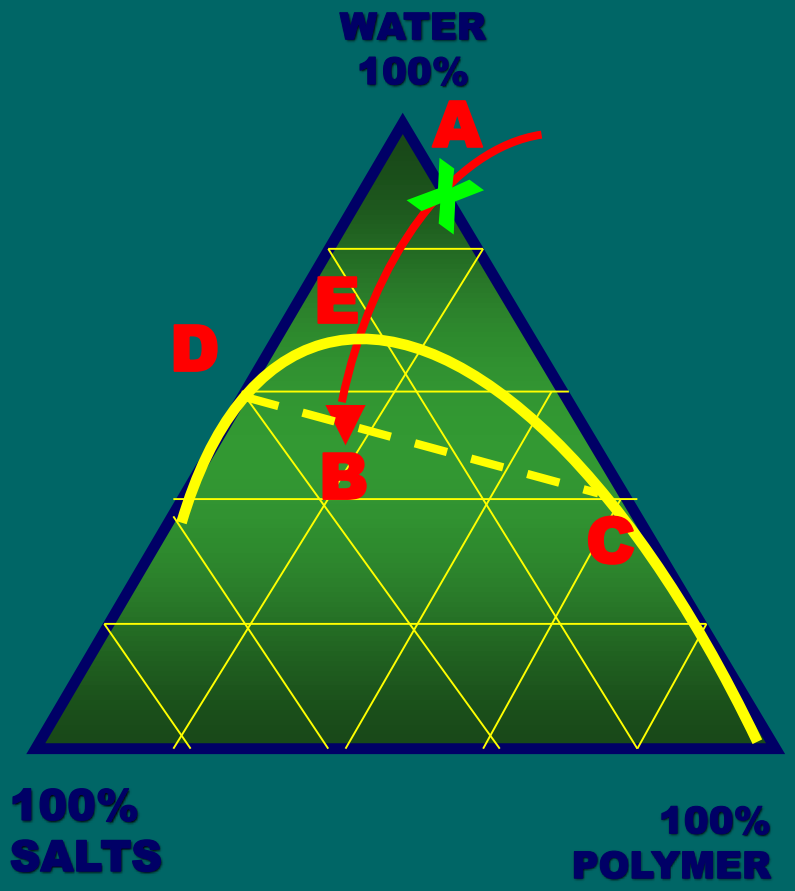
The resulting immiscible, liquid polymer can be utilized to microencapsulation of an immiscible core material.



Phase diagram for phase-separation/ coacervation induced by Non Solvent Addition

Salt Addition

Soluble inorganic salts can be added to aqueous solutions of watersoluble polymers to cause phase separation. As sodium sulfate.



Phase diagram for phase-separation/ coacervation induced by Salt Addition

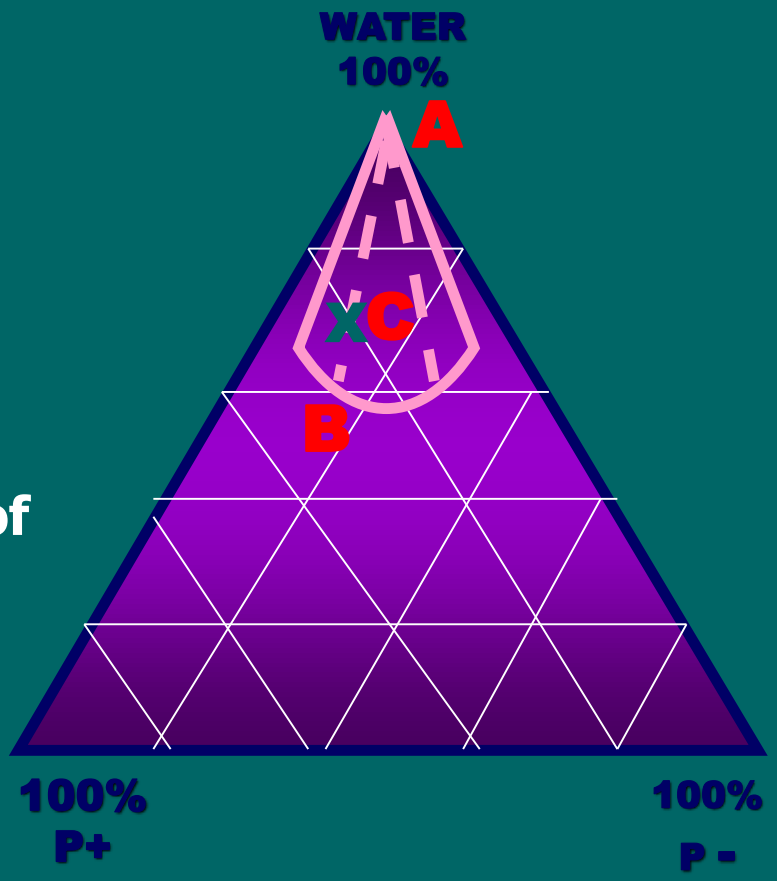
Polymer-Polymer Interaction (Complex Coacervation)

The interaction of oppositely charged polyelectrolytes can result in the formation of a complex having reduced solubility and phase separation occurs.

Complex coacervation process consists of three steps:

1. Formation of an O/W emulsion
2. Formation of the coating
3. Stabilization of the coating

The phase diagram for a ternary system comprised of two dissimilarly charged polyelectrolytes in water (as solvent).

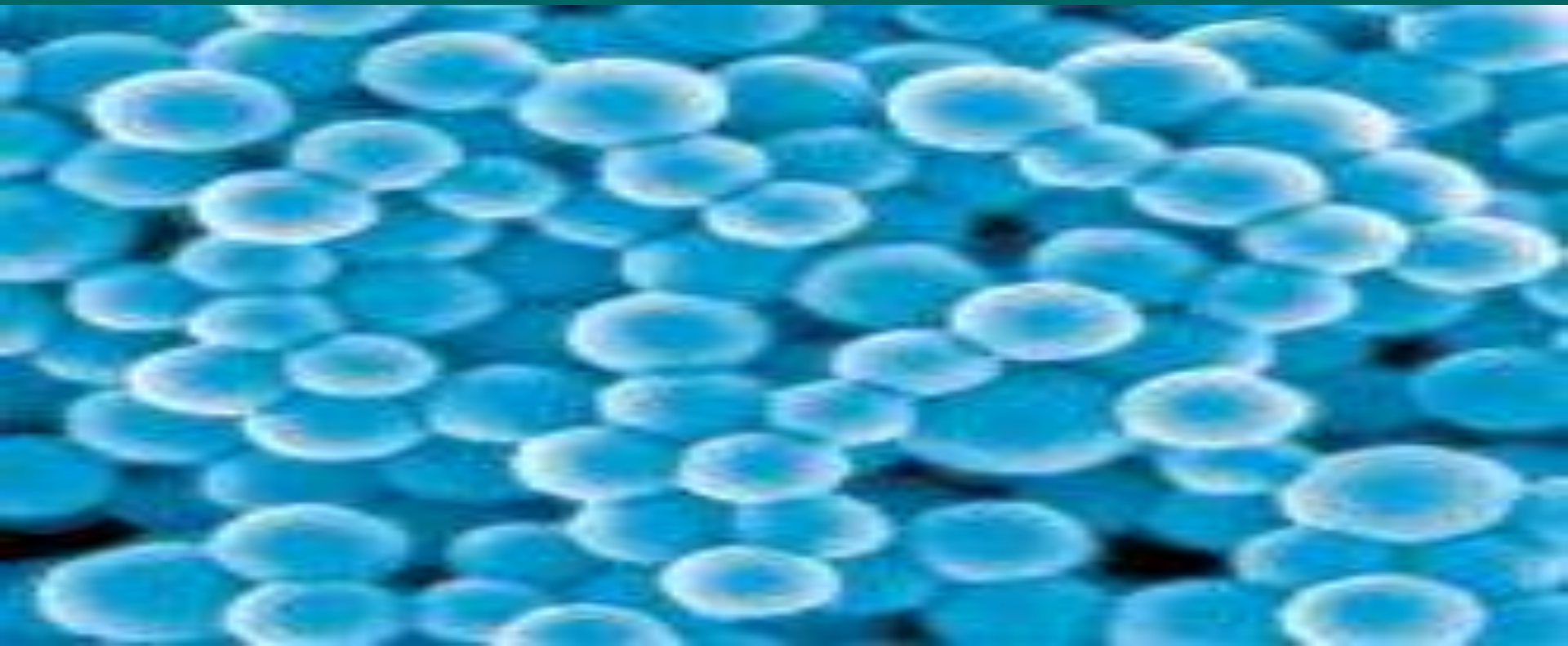


Phase diagram for phase-separation/ coacervation induced by Polymer Interaction

- **In the dilute solution region, interaction of the oppositely charged polyelectrolytes occurs, inducing phase separation within the phaseboundary curve *ABA.***
- **The segmented tie-lines indicate that a system, having an overall composition within the two-phase region (point C for example), consists of two phases, one being polymer poor, point *A,* and one containing the hydrated, liquid complex, Pe+ and Pe-, point *B.***

- Gelatin and gum arabic are typical polyelectrolytes that can interact.
- Gelatin, at pH below its isoelectric point, possesses a positive charge, whereas the acidic gum arabic is negatively charged.
- Under the proper temperature, pH, and concentrations, the two polymers can interact through their opposite electrical charges, forming a complex that exhibits phase-separation/coacervation.

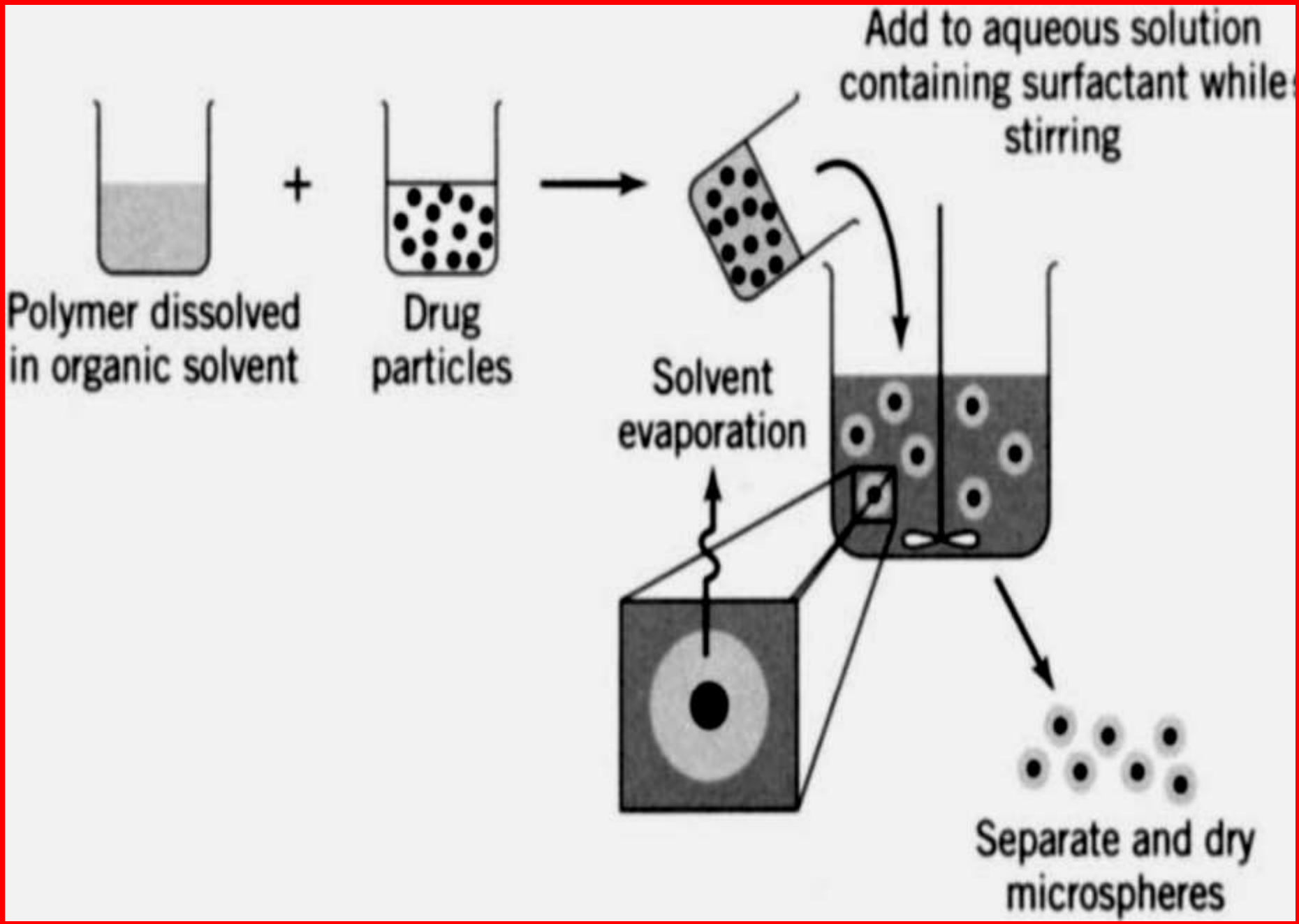
- Typical drying methods such as spray, freeze, fluid bed and tray drying techniques can be used in the microencapsulated products.
- Microcapsules can be manufactured by phase-separation/coacervation processes in large scale in vessels up to 2000 gallons in capacity.



Solvent evaporation

This method of microencapsulation is the most widely used due to:

1. *Simple technique .*
2. *this method allow encapsulation of hydrophobic and hydrophilic drug*
3. *this method allow encapsulation of solid and liquide drug*
4. *Microcapsule produced have wide size rang (5-5000µm)*


Add to aqueous solution containing surfactant while stirring
Polymer dissolved in organic solvent
Drug particles
Solvent evaporation
Separate and dry microspheres

Pan Coating

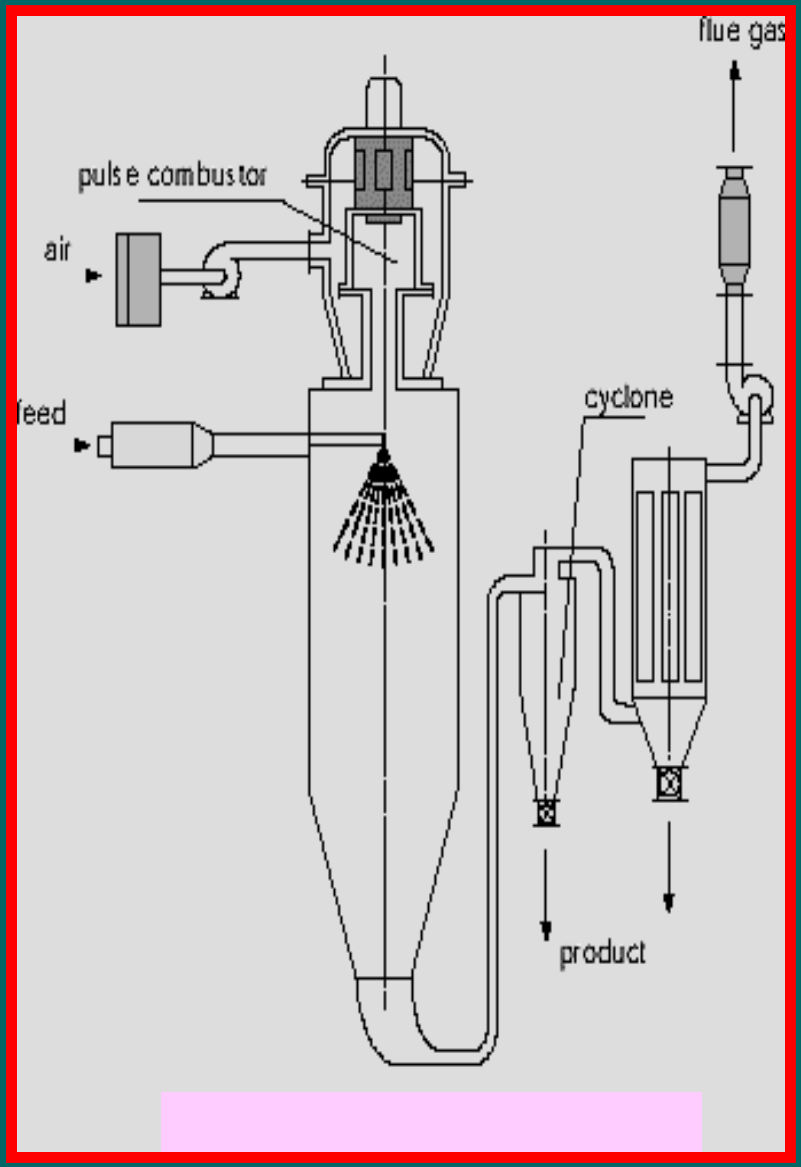
- Pan Coating process is used for solid particles greater than 600 microns in size.
- The coating is applied as a solution, or as an atomized spray, to the desired solid core material in the coating pan.
- Warm air is passed over the coated materials as the coatings are being applied in the coating pans to remove the coating solvent.
- Final solvent removal is accomplished in a drying oven.
- The coating operation is repeated three times. Then coating followed by dusting with talc the microcapsules are rolled until drying, and the excess talc is removed by vacuum.
- The product is then screened through a 12mesh screen.

Spray Drying and Spray Congealing

The Spray dryer equipment components include :

- **An air heater**
- **Atomizer spray chamber**
- **Fan**
- **Cyclone**
- **Product collector.**

Microencapsulation is conducted by dispersing a core material in a coating solution, in which the coating substance is dissolved and in which the core material is insoluble, and then by atomizing the mixture into a heated air stream.



- Microencapsulation by *spray-congealing* can be accomplished with spray drying equipment when the coating is applied as a melt .
- General process variables and conditions are quite similar to those spray drying , except that the core material is dispersed in a coating material melt rather than a coating solution.
- Waxes, fatty acids polymers , alcohols, and sugars, which are solids at room temperature but meltable at reasonable temperatures, are applicable to spray-congealing techniques.
- Coating solidification (microencapsulation) is accomplished by spraying the hot mixture into a cool air stream.

Microcapsules add many functional benefits

- particularly in skin care and treatment products include :

- Acting as controlled release vehicles
- Offering stabilization of materials that would otherwise be unstable.
- Act as delivery enhancers for active ingredients.
- Complex coacervation allows core contents to be varied to include almost any combination of oils, waxes, fats, butters, flavors, lipophilic actives, fragrances and other beneficial additives .