Pharmaceutical Technology

Lecture 24 and 25

Coarse Dispersion

Suspensions

Suspensions

- Suspension is a coarse dispersion containing finely divided insoluble material suspended in a liquid medium or available in a dry powder to be distributed in the liquid when desired, this in case the stability of powder is low.
- Suspension consist of two phases; solid dispersed phase and dispersion medium, which is liquid and may be oil or water.
- The particle size of coarse particles usually 10-50 µm in size.
- Suspension could be administer orally, topically, parenterally (except I.V), and for ophthalmic administration.

- Some suspensions preparations are available in:

1. Ready-to use form- that is, already distributed through a liquid vehicle with or without stabilizers and other pharmaceutical additives.
2. Other preparation are available as dry powders intended for suspension in liquid vehicles. This type of product generally is a powder mixture containing the drug and suitable suspending and dispersing agents, which upon dilution and agitation with a specified quantity of vehicle (generally purified water) results in the formation of a suspension suitable for administration.

- This type of preparation is designated in the USP by a title of the **"drug powder for oral suspension".**
- Prepared suspensions not requiring reconstitution at the time of dispensing are simply designated as **"drug oral suspension"**

Examples of suspension preparations

FIGURE 14.2 Commercial antibiotic preparation for oral suspension following reconstitution with purified water. *Left*, dry powder mixture. *Right*, suspension after reconstitution with the specified amount of purified water.

Reasons for suspensions

- There are several reasons for preparing suspensions

1. Certain drugs are chemically unstable when in solution but stable when suspended. In instances such as this, the suspension insures chemical stability while permitting liquid therapy.
2. For many patients, the liquid form is preferred over the solid form of the same drug because of the ease of swallowing liquids and flexibility in the administration of a range of dose. This particularly advantageous for infants, children and the elderly.
3. The disadvantage of a disagreeable taste of certain drugs when given in solution form is overcome when the drug is administered as undissolved particles of an oral suspension.

- Suspension given as intramuscular injection, because absorption from a suspension is normally slower than from solution at the injection site, and thus prolong the time of action of drug.
- By using an oil further slower down absorption and provide sustained or prolong action.
- Externally used suspension are either formulated in aqueous or oily vehicle depending on the intended of their use.
- For parenteral and ophthalmic use suspension should be sterile, and smaller particle size (less than 10µm)

What are the properties of ideal suspension

- The properties of acceptable ideal suspension are:

1. It should have a uniform particle size so that each particle acts as other particles producing constant behavior for the suspension as a whole.
2. No particle-particle interaction (no aggregation) and no clamping should occur; such suspension is called monodispersed suspension.
3. Their should be no sedimentation, the particles should either be stationary or moved randomly through out the dispersion so that there is always uniform dispersion of the drug.
4. The suspension should not be too viscous and pour freely.
5. It should have an agreeable odor, color, and taste.
6. It must not be decomposed or support microbial growth during storage.

- The properties or parameters that could be controlled in an attempt to reach ideal behavior are:

1. Particle size: it is desirable to have small particle size.

➢ In colloidal system Brownian movement keeps the particles movement, while in coarse dispersion as in suspension the particle size are too large for the terminal energy to keep them suspended and their will be always some degree of sedimentation.

- The terminal velocity with which particles settle in a coarse dispersion is expressed by stokes law:

$$\frac{dx}{dt} = V = \frac{d^2(\rho - \rho_0)\, g}{18\,\eta}$$

- Where, V is the terminal velocity or sedimentation rate of fall of an average particle in the dispersion (perfectly spherical particles).
- d is the mean particle diameter.
- ρ is the density of the particles
- ρ_0 is the density of the dispersion medium.
- G is acceleration constant due to gravity
- η is the viscosity of the dispersion medium.

- Diameter is important factor because it is raised to the 2nd power.
- So by reducing the diameter by reducing particle size using mortar and pestle the terminal velocity is decreased. Thus decrease sedimentation of particles.

- Mills is used for hard substances like crystals.

2. Particle movement and density and viscosity of medium.

A. If the density of solid equal the density of the dispersion medium then the rate of sedimentation V equal zero, which means ideal condition; **but this condition is hard to get, because**

- it is difficult to prepare a suspension with density great enough to match the density of a solid.
- Also the density of a solution is affected by the temperature, so density matching is useful only at control temperature.

B. Viscosity adjustment is better control of movement of sedimentation that by increasing it to a certain extent will decrease the sedimentation rate because there is an inverse proportion between them referring to Stokes' law, and this done by

- adding a thickening or suspending agent to increase the viscosity of the dispersion medium.
- Hydrophilic colloids are commonly used specially gums; cellulose, clays.

Example

- A powder has a density of 1.3 g/cc and is available as a powder with an average particle diameter of 2.5 microns (assuming the particles to be spheres). According to stokes Equation, this powder will settle in water (viscosity of 1cps assumed)at a rate of:

$$V = \frac{(2.5 \times 10^{-4})^2 (1.3 - 1.0)(980)}{18 \times 0.01} = 1.02 \times 10^{-4} cm/sec$$

- If the particle size of the powder is reduced to 0.25 μ and water is still used as the dispersion medium, the powder will now settle at a rate of:

$$V = \frac{(2.5 \times 10^{-5})^2(1.3 - 1.0)(980)}{18 \times 0.01} = 1.02 \times 10^{-6} cm/sec$$

- As is evident, a decrease in particle size by a factor of 10 results in reduction in the rate of settling by a factor of 100,
- This enhanced effect is a result of the “d” factor in stokes’ equation being squared.

- Now, if a different dispersion medium, such as glycerin is used in place of water, a further decrease in settling will result.
- Glycerin has a density of 1.25g/cc and a viscosity of 400 cps. The larger particle size powder (2.5 µ) will settle at a rate of:

$$v = \frac{(2.5x10^{-4})(1.3 - 1.25)(980)}{18\,x\,4} = 4.25\,x\,10^{-8}\,cm/sec$$

- The smaller particle size (0.25µ) powder will now settle at a rate of:

$$v = \frac{(2.5x10^{-5})(1.3 - 1.25)(980)}{18\,x\,4} = 4.25\,x\,10^{-10}\,cm/sec$$

- A summary of these results is shown in the following table:

Condition	Rate of settling (cm/sec)
2.5µ powder in water	1.02×10^{-4}
0.25µ powder in water	1.02×10^{-6}
2.5µ powder in glycerin	4.25×10^{-8}
0.25µ powder in glycerin	4.25×10^{-10}

- As is evident from this table, a change in dispersion medium results in the greatest change in the rate of settling of particles. Particle size reduction can contribute significantly to suspension stability. These factors are important in the formulation of physically stable suspensions.

3. Concentration of solid:

- High concentration of solid increase the possibility of particle-particle collision, but will also promote particle-particle interaction.
- The concentration of solid is usually fixed in prescription and can not be changed to affect the stability purpose.

4. Particle-particle interaction

- Particle-particle interaction controls the deflocculation and flocculation system. Particle-particle interaction must be avoid because the aggregation of small particle will behave as single large particle and tend to settle at increase rate of flocculation.
- If particle have similar electric charge then they preventing from coming together. It is usually for solid particles dispersed in aqueous media to carry the same type of charge.

- There are varies ways where charge can developed:

1. Ionization of groups on solid surface.
2. Adsorption of surfactant on solid surface.
3. Adsorption of electrolyte from solution.

- The last two methods are the most common. The sign of charge develop on the surface of particle can be predicted if the charge result from adsorption of sodium lauryl sulphate on the solid will make the solid carry negative charge.
- The sign of charge which develop from electrical charge adsorption depend on the ion adsorption from the solution and it is difficult to be predicated.
- The magnitude of charge is define as: the difference in electrical potential between the charge of solid surface and bulk of the solution.

5. Particle-vehicle interaction: these are significant in wetting and dispersion particle. When solid is reduced to small particle size, there is an increase in surface area ΔA and surface free energy ΔF, so the particle now is highly energetic and tend to come together to reduce the free energy.

- From thermodynamic point of view:

  $$\Delta F = \Upsilon_{sL} \cdot \Delta A$$

- It is better to decrease ΔF by controlling the Υ_{sL} rather than ΔA. Controlling of Υ_{sL} is happen by adding surfactant which will result in dispersion of particle in the media. So these wetting agents will decrease the tendency of particle to flocculate by dispersing them.

- The wetability of lyophobic powder may increase by passing the material through colloid mills in presence of wetting agent like alcohol, glycerin, and other hygroscopic materials which are used as initial wetting agent in suspension manufacturing.
- These liquid cause:

1. Displace air
2. Disperse the particle
3. Allow the penetration of vehicle into powder

Sedimentation parameters (Index of flocculation)

- Sedimentation parameters are:

1. Sedimentation volume (F)
2. Degree of flocculation (β)

- These parameters are used as semi quantitative measure of flocculation in suspension.
- Sedimentation volume (F) for flocculated suspension = V_u/V_o

➢ Where

- V_u the ultimate volume of the sediment.
- V_o the the original volume of suspension, before settling.
- For deflocculated suspension:

$F_\infty = V_\infty / V_o$

- F may have one the following values:

1. $F < 1$
2. $F > 1$
3. $F = 1$

- F less than 1 is ordinary case, when the suspension settle to a certain volume of sediment less than the volume of suspension.
- F greater than 1, it is a rare case, when the ultimate volume of sediment become greater than original volume of the suspension. This occurs when the particles form a loose fluffy network in the vehicle so the final volume of the sediment is greater than original volume.
- F equal to 1 when the product shows no clear supernatant when the both volumes are equal i.e., Vu =Vo. It is in state of flocculation equilibrium, it is an acceptable product.

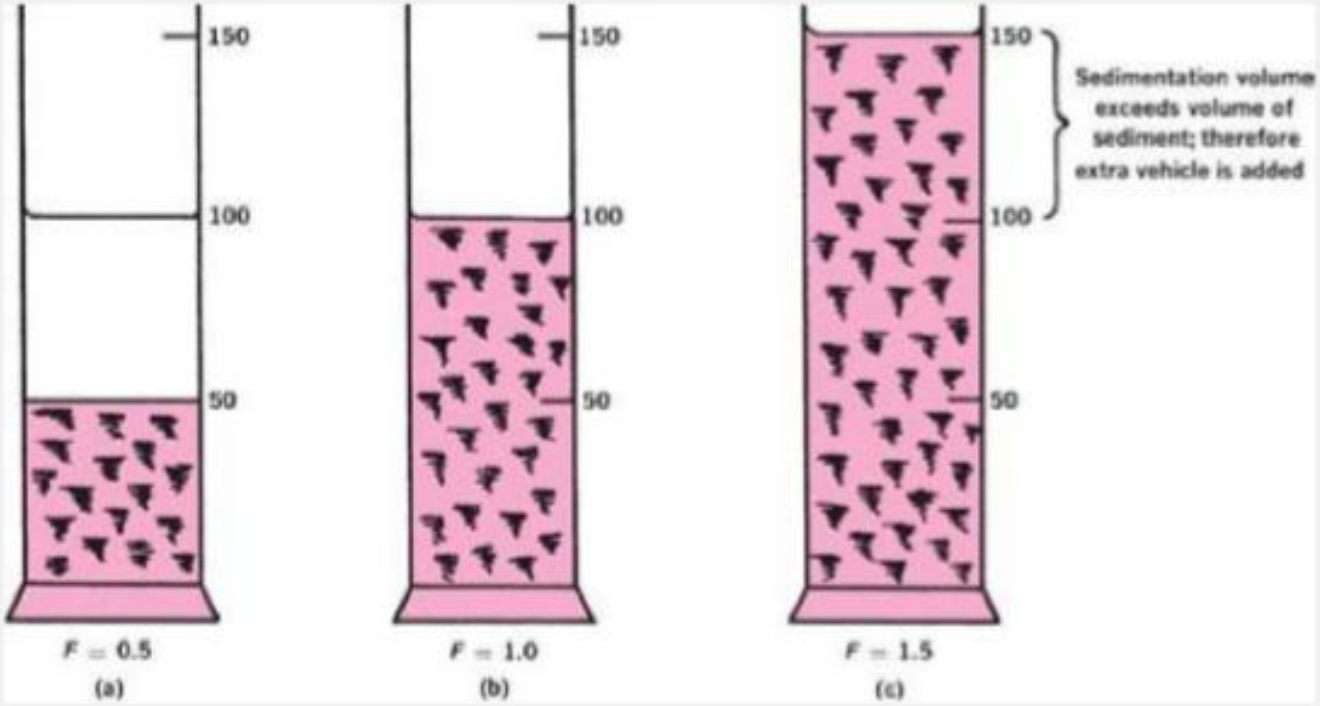


Fig. 17-2. Sedimentation volumes produced by adding varying amounts of flocculating agent. Examples (*b*) and (*c*) are pharmaceutically acceptable.

Sedimentation parameter
(Degree of flocculation)

- The second parameter is degree of flocculation(β). It is a better parameter for evaluating flocculation in a suspension, it describes the relationship between the sedimentation volume of the flocculated suspension (F) to the sedimentation volume of the same suspension when deflocculated (F_∞).
- The following equation is used to calculate β

$$\beta = \frac{F}{F_\infty} = \frac{v_u/v_0}{v_\infty/v_0} = \frac{v_u}{v_\infty}$$

- Where,
  - v_u is the ultimate volume of flocculated suspension
  - v_∞ is the ultimate volume of deflocculated suspension

- A suspension consisting of floccules held together loosely will have large β, while suspension containing sediment has small β.
- The lower limit of β is equal to 1; which means there is no flocculation, i.e., $v_u = v_\infty$

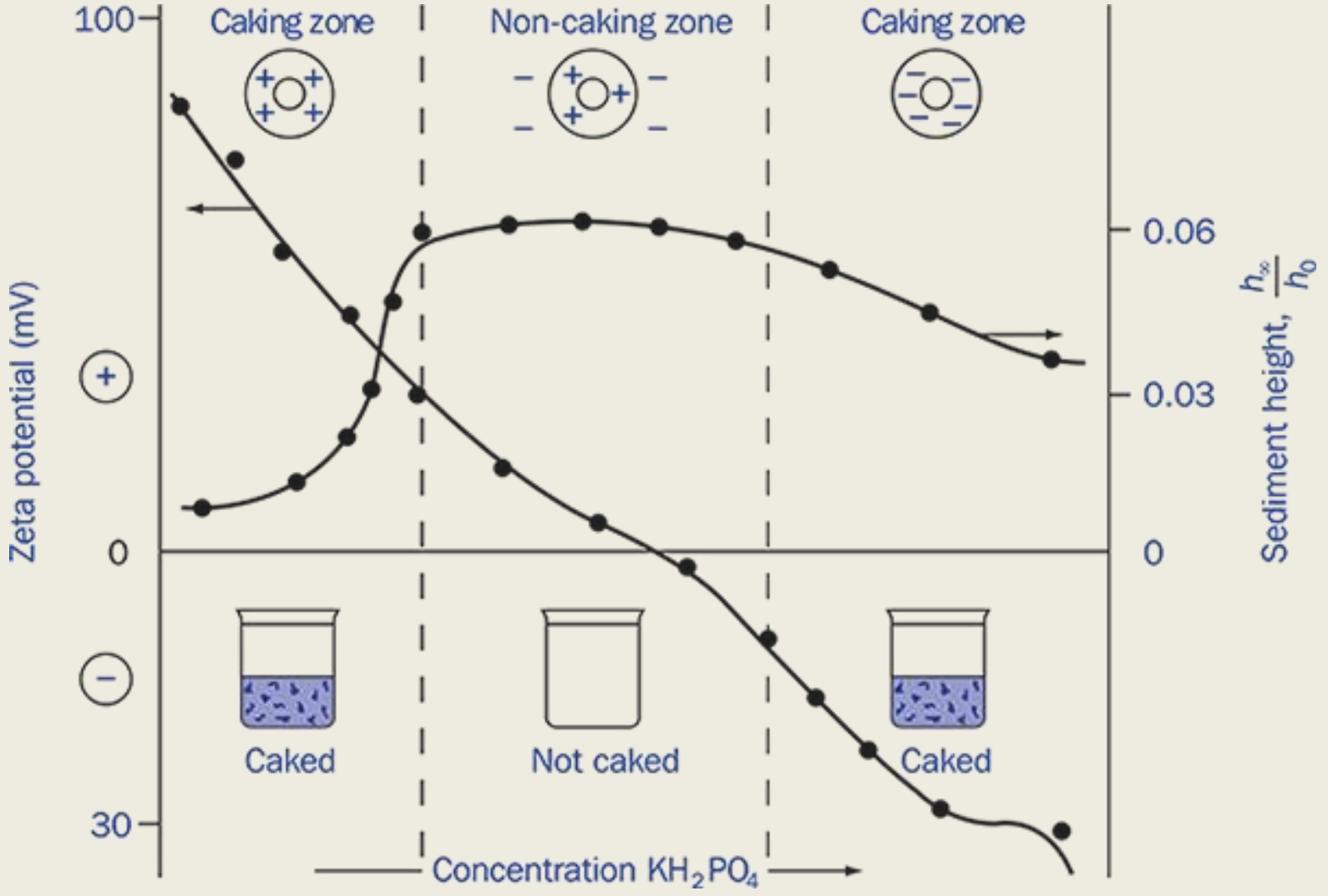
- How can you induce flocculation?
- You can do that by use of flocculating agents, such as

1. Electrolytes
2. Surfactants and
3. Polymers.

- Flocculating agents are agents that are added to the medium to promote flocculation by counter acting the effect of protective layer the thus decrease zeta potential.

1. Electrolytes: they are used to obtain a product of large sedimentation volume. The ions will reduce the electrical barrier between the particles and link them together by forming a bridge between the particles, so the particles are held loosely in the suspension, but these large aggregates although settles rapidly they are easily redispersed by agitation.

- The addition of electrolytes may be illustrated by the addition of monobasic potassium phosphate (KH_2PO_4) as a negative flocculating agent to a suspension of bismuth subnitrate (the particles of which are positively charged).


100
Caking zone
Non-caking zone
Caking zone
Zeta potential (mV)
+
0
−
30
0.06
0.03
0
Sediment height, $\frac{h_\infty}{h_0}$
Caked
Not caked
Caked
Concentration KH_2PO_4

- Initially, the bismuth subnitrate particles have a large positive charge with the addition of (KH_2PO_4) the apparent zeta potential will decrease to a point where the system have maximal flocculating.
- sedimentation study on bismuth subnitrate with increasing concentrations of flocculating agent have shown that:

1. The sedimentation volume is low initially, a condition that suggests a close-packed sediment of bismuth subnitrate particles.
2. Flocculation by KH_2PO_4 will increase the sediment volume relative to the initial value; until it reaches a maximum value. This is known as noncaking zone.
3. Additional flocculating agent will neutralize the charge on the particles and finely it will reverse the charge from +ve to –ve and again we get a caked suspension.

- The bridging action of the flocculated agent is more important than the neutralization of surface charge on the particles.

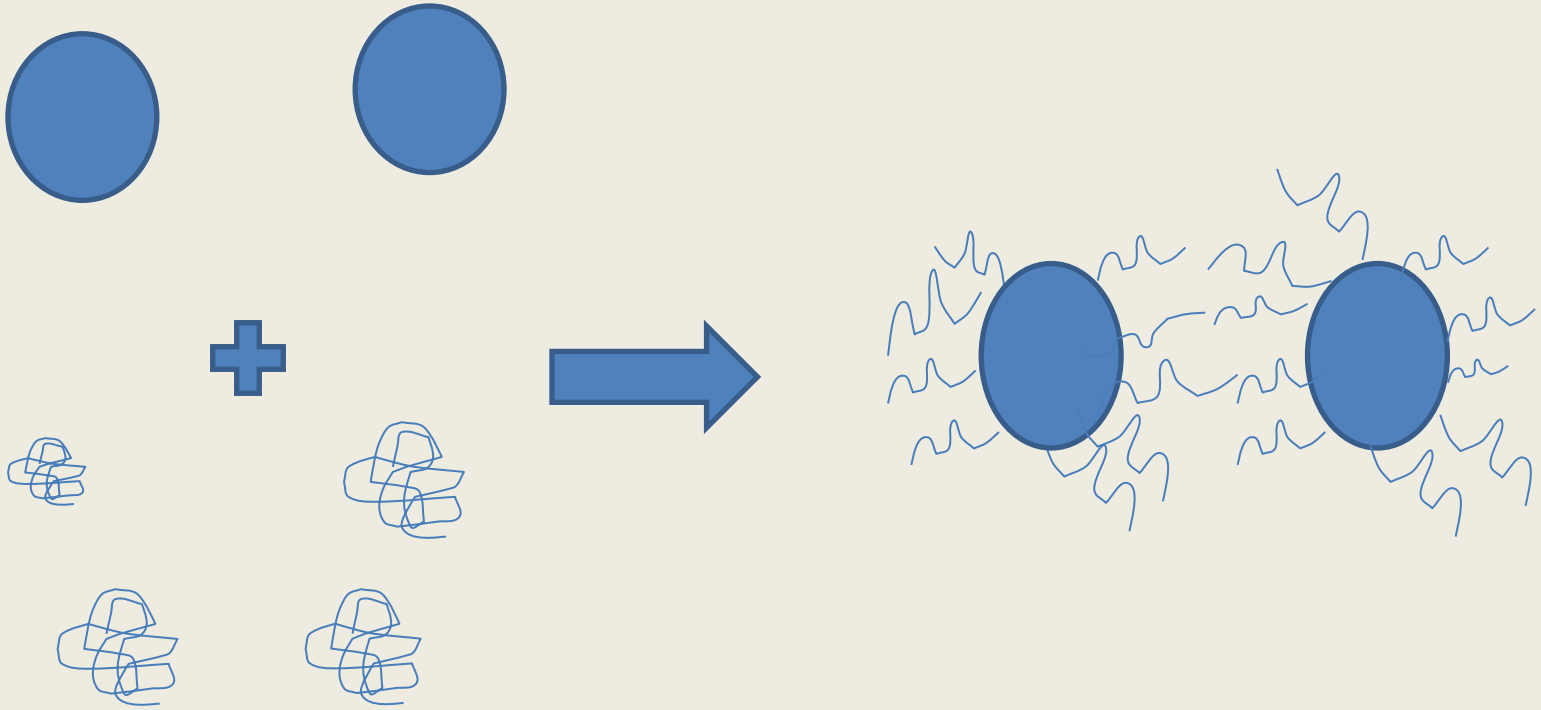
2. Surfactant: Both ionic and non-ionic surfactants are used to bring about flocculation of suspended particles.

- Ionic surfactant increases sedimentation volume, while non-ionic surfactant may be adsorbed onto suspended particles and produce flocculated system at certain concentration.
- Optimum concentrations of surfactants bring down the surface free energy by reducing the surface tension between liquid medium and solid particles.
- The particles possessing less surface free energy are attracted towards to each other by Van der waals forces and forms loose agglomerates.

3. Polymers: lyophilic polymers are commonly used as suspending agent.

- The polymer molecules contain active groups spaced along molecules may be adsorbed on the particles, leaving extended segments projecting out from the particle for bridging across to adjacent particles and thus producing flocculated system.

Flocculation by polymers



- A number of hydrocolloids are polyelectrolytes, their flocculating action is dependent on the pH of the medium and the ionic strength, and there is an optimum pH for sedimentation.
- For example, gelatin, which is a natural hydrocolloid may be used to bring about flocculation and prevent caking.

Properties of flocculated and deflocculated suspensions

Flocculated suspension	Deflocculated suspension
1. Particles form loss aggregate	1. Particles exist in suspension as separate entities
2. Rate of sedimentation is high, since particles settle as floc, which is a collection of particles	2. Rate of sedimentation is low, since each particle size is minimal.
3. A sediment is formed rapidly	3. A sediment is formed slowly
4. The sediment is loosely packed and possesses a scaffold like structure.	4. The sediment eventually becomes very closely packed, owing to weight of upper layers of sediment material.
5. The sediment does not form hard cake and easily re-disperse.	5. Hard cake is formed which is difficult to re-disperse
6. The suspension in some what unpleasant due to rapid sedimentation and presence of obvious clear supernatant region.	6. The suspension has a pleasing appearance since the suspended material remains suspended for a relative long time. The supernatant remains cloudy even when settling is apparent.
7. The floccules stick to the sides of the bottle	7. Particles do not stick to the sides of the bottle

Suspending agents

- Suspending agents are substances that are used to keep finely divided insoluble materials suspended in a liquid media by preventing their agglomeration (coming together) and by imparting viscosity to the dispersion media so that the particles settle more slowly.
- Suspending agents form film around particle and decrease interparticle attraction.
- There are various types suspending agents

Types of suspending agents

1. Natural agents: this class consists of
A. Animal source: e.g., gelatin
B. Plant source: e.g., acacia, tragacanth, starch, sea weed.
C. Mineral source: e.g., bentonite, kaolin.
2. Semi-synthetic agents: these consist of substituted cellulose, e.g. methyl cellulose.
3. Synthetic agents: they are synthetic polymer, e.g., Carbopols.

- A good suspension should have well developed thixotropy:

➢ At rest the solution is sufficient viscous to prevent sedimentation and thus aggregation or caking of the particles.

➢ When agitation is applied the viscosity is reduced and provide good flow characteristic from the mouth of bottle.

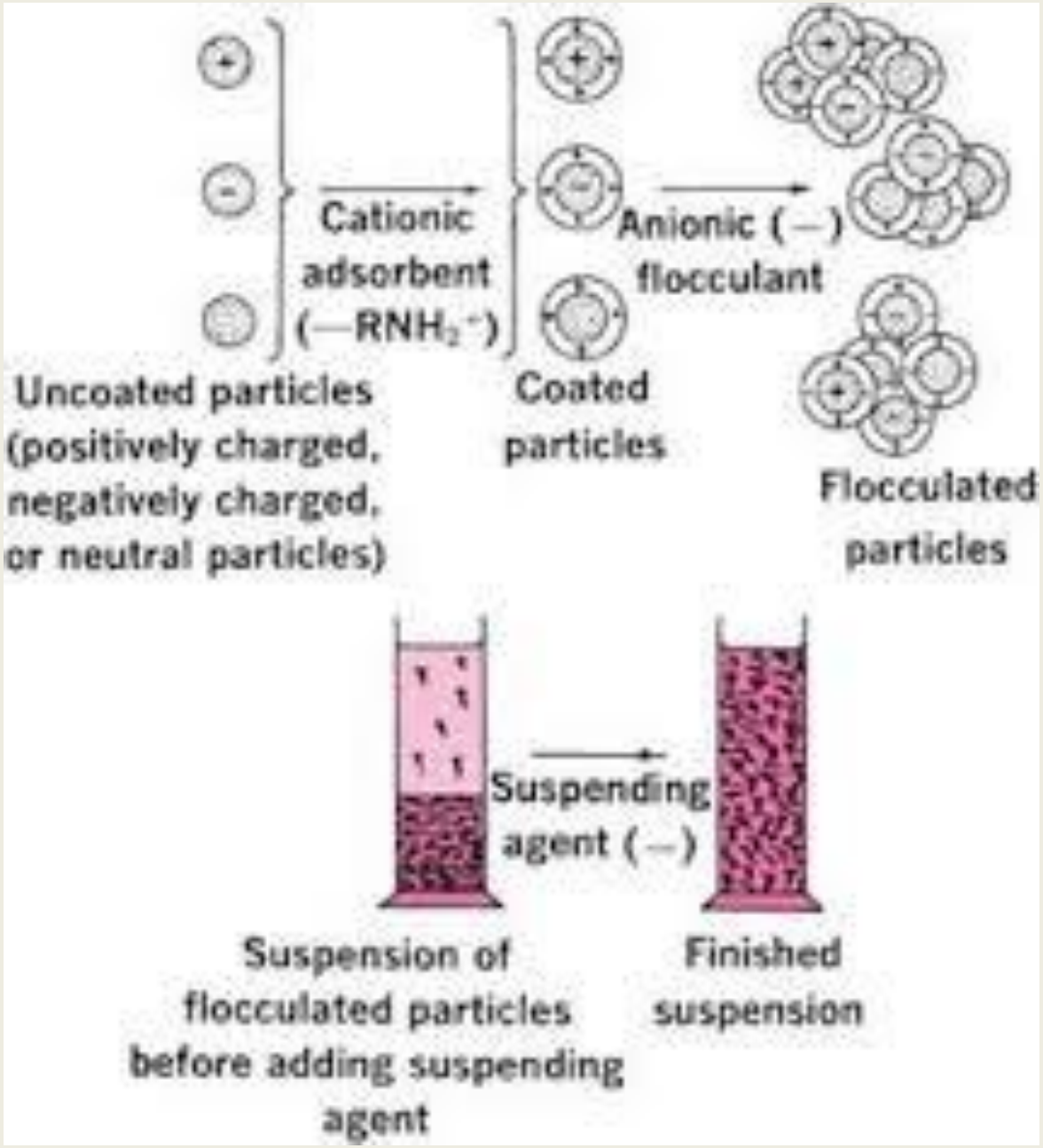
The Design of Acceptable Suspensions

- In practice, a highly flocculated suspension cannot be marketed as such because the particles settle rapidly and ordinarily leave a supernatant layer which is unsightly.
- Consequently, a suspending agent with appropriate rheological properties such as carboxymethylcellulose, bentonite, Carbopol or a combination of these materials is added to produce a final product with sufficient structure to support flocs but not so rigid as to prevent flow when the material is agitated and poured from the container.

- Most suspending agents are belong to the class of negatively charged hydrophilic colloids and when added to suspension containing positively charged flocculating agents they tend to produce an unsightly stringy mass of coagulated suspending agent which settles rapidly and fails in its suspending action.
- Phosphate ions and other negatively charged agents which are used to flocculate positively charged particles are compatible with the commonly used suspending agents and they have no serious problems.

- The difficulty with negatively charged drugs which may be overcome by adsorbing onto the drug particles certain agents which reverse the surface charge from negative to positive.
- ✓ This can be accomplished by the use of fatty acid amines, gelatine at a pH below its isoelectric point or other positively charged molecules, then
- ✓ KH_2PO_4 or another anionic flocculating agent can bring about the appropriate flocculation.

- These flocculating agents are compatible with the commonly used suspending agents.
- The technique of adsorbing a positively charged substance on suspension particles followed by flocculation with a negative ion and finally stabilization of the product with a negatively charged suspending agent is illustrated in the following Figure.


Cationic adsorbent (—RNH$_2$$^+$)
Anionic (−) flocculant
Uncoated particles (positively charged, negatively charged, or neutral particles)
Coated particles
Flocculated particles
Suspending agent (−)
Suspension of flocculated particles before adding suspending agent
Finished suspension

➢The steps in this scheme are as follows:

1- The particles irrespective of their charge are coated with a (+ve) agent which must be checked for lack of toxicity before use.

2- The particles are flocculated by the use of a (-ve) agent to bring the product into the noncaking zone.

3- Finally, a minimum amount of a suspending agent is added and the suspension is again observed for optimum flocculation and freedom from caking.

Preparation of suspensions

- In the preparation of a suspension, the pharmacist must be familiar with the characteristics of both the intended dispersed phase and the dispersion medium.
- In some instances, the dispersed phase has an affinity for the vehicle to be employed and is readily wetted by it. Other drugs are not penetrated easily by the vehicle and have a tendency to clump together or to float on the vehicle.
- In the latter case, the powder must first be wetted to make it more penetrable by the dispersion medium. Alcohol, glycerin, propylene glycol, and other hygroscopic liquids are employed as wetting agents when an aqueous vehicle is to be used as the dispersion phase.

Ingredients for formulation of suspensions

1. Wetting agents: these agents are added to disperse solids in continuous phase.
2. Flocculating agents: these agents are added to floc the drug particles
3. Thickeners: these agents are added to stabilize the suspension.
4. Buffers and pH adjusting agents: these agents are added to adjust the suspension to a desired pH range.
5. Osmotic agents: these agents are added to adjust osmotic pressure comparable to biological fluid.
6. Coloring agents; these agents are added to impart desired color to suspension and improve elegance.
7. Preservatives: these agents are added to prevent microbial growth.
8. External liquid vehicle: these agents are added to construct structure of the final suspension.

Types of suspension

I. **According to route of administration:**

1. Oral suspensions should be taken by oral route and therefore must contain suitable flavoring and sweetening agents.
2. Topical suspensions meant for external application and therefore should be free from gritty particles
3. Parenteral suspensions should be sterile and should possess property of syringability.
4. Ophthalmic suspensions should be sterile and should possess very fine particles
5. Otic suspension
6. Rectal suspension

II. According to the size of solid particles

1. Coarse suspension (> 1 µm)
2. Colloidal suspension (< 1 µm)
3. Nano suspension (10-100 nm)

III. According to nature of sediment:

1. Flocculated suspension
2. Deflocculated suspension

IV. According to proportion of solid particles

1. Diluted suspension (2 to 10% w/v solid), e.g., predinsolone acetate suspension
2. Concentrated suspension (50% w/v solid), e.g., zinc oxide suspension

A suspension containing diffusible substances

1. They contain insoluble but easily dispersible solids
2. These solid are light and easily wettable substances
3. Readily mixed with water and on shaking diffuse evenly throughout the liquid long enough to ensure even distribution and a dose to measure.
4. The sediment forms slowly

- Examples: light kaolin, magnesium tri silicate, light calcium carbonate, magnesium carbonate

V. According to nature of dispersed phase and methods of preparation: The suspensions are classified as suspensions containing

1. diffusible solids,
2. indiffusible solids,
3. poorly wettable solids,
4. precipitate forming liquids
5. Dispersion of oils in inhalations
6. products of chemical reactions.

Suspensions containing indiffusible solids

1. These solids are insoluble powders and will not remain evenly distributed in a vehicle long enough to ensue uniformity of dose
   - For example zinc oxide, calamine powder, aspirin and phenobarbitone
2. The sediment too rapidly forms and requires the addition of other materials to reduce sedimentation rate to an acceptable level.
   - For example thickening agent to increase viscosity, decrease sedimentation rate and avoid collision of particles.

Suspensions containing poorly wettable substances

1. The particles are both insoluble and poorly wettable in water.
   - Examples: sulfur and hydrocortisone
2. The interfacial tension between particles and water is high, i.e., not diffusible in water.
3. Wetting agents (e.g., surfactants) are added to decrease interfacial tension, thus affinity of the particles to the surrounding environment is increased and the interparticulate force is decreased.

Suspensions of precipitate forming liquids

1. Resinous materials when mixed with water become precipitated.
   - Examples: compound benzoin tincture, Tolu tincture
2. This type of suspension requires addition of protective colloid (thickening agent) .

Suspension containing of oil in inhalation

1. Used for suspension containing volatile oils
2. To ensure uniform distribution of oil, diffusible solid (magnesium carbonate) is used to adsorb some of the oil
3. The powder should not interfere with free vaporization of the oil when the inhalations are added to water at about 65°C for use.
4. If quantity is not mentioned 1 g of light magnesium carbonate for each 2 mL of oil or 2 g of volatile solid gives satisfactory result
5. For example menthol and eucalyptus oil inhalation

Suspension containing solid product of chemical reaction

1. Insoluble active constituents are formed by chemical reaction
2. The reaction substances should be dissolved separately in half volume of vehicle and two parts are mixed
3. Finer precipitate formed is diffusible and no suspending agent is necessary

Example of oral suspensions

1. Antacid suspension e.g., Aluminum, Magnesium and simethicone oral suspension.

- Antacids are intended to counteract the effects of gastric hyperacidity and, as such, are employed by persons, such as peptic ulcer patients, who must reduce the level of acidity in the stomach. They are also widely employed and sold over the counter (OTC) to patients with acid indigestion and heartburn.
- Most antacid preparations are composed of water-insoluble materials that act within the gastrointestinal tract to counteract the acid and/or soothe the irritated or inflamed linings of the gastrointestinal tract.

- A few water-soluble agents are employed, including sodium bicarbonate, but for the most part, water-insoluble salts of aluminum, calcium, and magnesium are employed; these include aluminum hydroxide, aluminum phosphate, calcium carbonate, calcium phosphate, magnesium carbonate, magnesium oxide, and magnesium hydroxide.

2. The antibacterial oral suspensions: include preparations of antibiotic substances (e.g., erythromycin derivatives and tetracycline and its derivatives), sulfonamides (e.g., sulfamethoxazole and sulfisoxazole acetyl), other anti-infective agents (e.g., methenamine mandelate and nitrofurantoin), or combinations of these (e.g., sulfamethoxazole–trimethoprim).

- Many antibiotic materials are unstable when maintained in solution for an appreciable length of time, and therefore, from a stability standpoint, insoluble forms of the drug substances in aqueous suspension or as dry powder for reconstitution are attractive to manufacturers.

- The dispersing phase of antibiotic suspensions is aqueous and usually colored, sweetened, and flavored to render the liquid more appealing and palatable.
- The palmitate form of chloramphenicol was selected for the suspension dosage form not only because of its water insolubility but also because it is flavorless, which eliminates the necessity to mask the otherwise bitter taste of the chloramphenicol base.

3. Dry Powders for oral suspension

A number of official and commercial preparations consist of dry powder mixtures or granules that are intended to be suspended in distilled water or some other vehicle prior to oral administration.

- As indicated previously, these official preparations have “for Oral Suspension” in their official title to distinguish them from prepared suspensions.
- Most drugs prepared as a dry mix for oral suspension are antibiotics.

- The dry products are prepared commercially to contain the antibiotic drug, colorants (FD&C dyes), flavorants, sweeteners (e.g., sucrose or sodium saccharin), stabilizing agents (e.g., citric acid, sodium citrate), suspending agents (e.g., guar gum, xanthan gum, methylcellulose), and preserving agents (e.g., methylparaben, sodium benzoate) that may be needed to enhance the stability of the dry powder or granule mixture or the liquid suspension.

- When called on to reconstitute and dispense one of these products, the pharmacist loosens the powder at the bottom of the container by lightly tapping it against a hard surface and then adds the label-designated amount of purified water, usually in portions, and shakes the slurry until all of the dry powder has been suspended .
- It is important to add precisely the prescribed amount of purified water to the dry mixture if the proper drug concentration per dosage unit is to be achieved

- Also, the use of purified water rather than tap water is needed to avoid the possibility of adding impurities that could adversely affect the stability of the resulting preparation.
- Generally, manufacturers provide the dry powder or granule mixture in a slightly oversized container to permit adequate shaking of the contents after the entire amount of purified water has been added.

4. Anthelmintics: e.g., Albenzadol oral suspension
5. Antifungals: e.g., Nystatin oral suspension

Package and storage of oral suspensions

- All suspensions should be packaged in wide mouth containers having adequate airspace above the liquid to permit adequate shaking and ease of pouring.
- Most suspensions should be stored in tight containers protected from freezing, excessive heat, and light.
- It is important that suspensions be shaken before each use to ensure a uniform distribution of solid in the vehicle and thereby uniform and proper dosage.
- Many of the oral suspensions that are intended primarily for infants are packaged with a calibrated dropper to assist in the delivery of the prescribed dose.

Examples of other suspensions

1. Otic suspensions: for example combination of polymyxin B sulfate, neomycin sulfate and hydrocortisone otic suspension.
2. Ophthalmic suspensions: Hydrocortisone eye drop suspension
3. Rectal suspensions: for example Barium sulfate for suspension may be employed orally or rectally for the diagnostic visualization.

- Commercially, barium sulfate for diagnostic use is available as a bulk powder containing the required suspending agents for effective reconstitution to an oral suspension or enema prior to administration.
- Enema units, which contain prepared suspension in a ready-to-use and disposable bag, are also available.

5. Parenteral suspensions: Most parenteral suspensions are designed for intramuscular or subcutaneous administration to control the rate of absorption.

- For example, Triamcinolone Acetonide Injectable suspension and insulin zinc suspension are intended for intramuscular (or intra-articular) and subcutaneous administration respectively.

6. Externally applied suspensions.

- For example calamine lotion; lotion when applied to skin solvent evaporates leaving a light deposit of medicament on the surface.

Applications of suspensions

1. Suspension is usually applicable for drug which is insoluble or poorly soluble.
2. Suspension is used to prevent degradation of drug or to improve stability of drug.
3. Suspension is used to mask the taste of bitter of unpleasant drug. For example chloramphenicol palmitate suspension.
4. Suspension can be formulated for topical application.

5. Suspension can be formulated for parenteral application in order to control rate of drug absorption.

- For example procaine penicillin G.

6. Suspension is used for formulation of vaccines (immunizing agent). For example cholera vaccine.
7. Suspension can be used as adsorbent of toxins in GIT, for example in soluble powers (kaoline and aromatic chalk) can be administered as suspension.

- Kaolin is used for mild-to-moderate diarrhea, severe diarrhea (dysentery), and cholera.
- Aromatic chalk powder (chalk powder): a powder ranging in colour from white to light-brown, containing chalk and cinnamon, nutmeg, cloves, cardamon and sugar.
- Chalk acts as an antacid and astringent on the intestinal canal; a little becomes absorbed and produces the remote effects of lime. It is used chiefly in diarrhea, alone or combined with other astringents and aromatics.