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Program	B. Pharmacy
Semester	1 st
Subject /Course	Pharmaceutical Inorganic and Analytical Chemistry
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Module No.	04
Module Title	Gastrointestinal agents: Antacids, Acidifiers, Agents promoting bowel movements, Antimicrobial agents and Radiopharmaceuticals.
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LO	Particular
1.	Differentiate various acidifiers, antacids, bowel movement promoters, and antimicrobial agents based on their pharmaceutical applications.
2.	Apply the knowledge of gastrointestinal agents for the appropriate selection and safe use in different clinical conditions.
3.	Differentiate various acidifiers, antacids, bowel movement promoters, and antimicrobial agents based on their pharmaceutical applications.
4.	Apply the knowledge of gastrointestinal agents for the appropriate selection and safe use in different clinical conditions.
5.	Differentiate various acidifiers, antacids, bowel movement promoters, and antimicrobial agents based on their pharmaceutical applications.

Module Content Table

Sr. no.	Topic
1.	Gastrointestinal agents Acidifiers: Sodium acid phosphate and Dilute Hydrochloric acid. Antacids: Ideal properties of antacids, combinations of antacids, Sodium bicarbonate*, Aluminium hydroxide gel*. Agents promote bowel movements: Magnesium hydroxide, Sodium orthophosphate, Sodium Potassium tartrate and magnesium trisilicate. Antimicrobials: Mechanism, classification, Potassium permanganate, Boric acid, Hydrogen peroxide*, Chlorinated lime*, Iodine and its preparations.
2.	Radiopharmaceuticals Basics of radioactivity, applications of radioisotopes of Sodium Iodide I-131, Technetium-99m, Cobalt-60, Phosphorus-32 including safe handling, storage, and disposal of radiopharmaceuticals, adhering to regulatory guidelines for safety.

Gastrointestinal Agents

INTRODUCTION

The digestive system is the gastrointestinal tract (GIT) which is a group of organs. It extends from the oesophagus to the anus. The entrance to the system is the buccal cavity. The main portions of GIT include the stomach, the small intestine (duodenum, jejunum, and ileum), the large intestine (caecum ascending, transverse and descending colons) and the rectum with the exit anus.

Stomach: In stomach, digestion of proteins in acidic medium takes place with pepsin enzyme. Both acid (HCl) and enzyme are secreted in the stomach by specialised cells.

Small intestines: In small intestines, the following changes take place:

- (i) Digestion of proteins takes place in alkaline medium in the presence of enzymes.
- (ii) Digestion of carbohydrates and lipids take place in the presence of enzymes and bile salts.
- (iii) Absorption of digested foods, vitamins and minerals take place.

Whenever the above functions go wrong, there occur diseases or undesirable conditions. Some of these are as follows:

- (i) Whenever inadequate secretion of acid takes place in the stomach, this causes **achlorhydra or hypochlorhydeia**.
- (ii) Whenever excess secretion of acid takes place in the stomach, this causes the imbalance of acid- enzyme ratio, thereby finally leading to **hyperacidity and ulcers**. Gastric and sometimes duodenal wall become sensitive giving rise to acute pain.
- (iii) There may occur accumulation of toxic substances or gases.
- (iv) There may occur inadequate absorption of fluids and minerals from large intestine, thereby causing **diarrhoea**.
- (v) There may occur insufficient peristaltic movement of large intestine thereby causing **constipation**.
- (vi) There may occur inadequate secretion of saliva, thereby making the food to swallow with difficulty.

It is possible to correct the above conditions by administration of suitable drugs.

Classification of gastrointestinal agents

- Acidifiers
- Antacids
- Agents promoting bowel movements
- Antimicrobials

ACIDIFYING AGENTS OR ACIDIFIERS

Acidifiers are inorganic compounds that increase the acidity (lower the pH) of body fluids such as the stomach or urine (increases level of gastric acid in stomach when ingested, thereby decreases the stomach pH). They are used to restore normal acidic conditions when there is a deficiency of acid production or when acidification is required for therapeutic purposes. Acidifiers improve digestion, enhance the absorption of certain nutrients, and help maintain the normal physiological functions of the gastrointestinal and urinary systems. Acidifiers are classified into four categories:

1. Gastric Acidifiers: These are the drugs which are used to increase the acidity of the stomach in patients suffering from Achlorhydria or Hypochlorhydria (absence or insufficient quantity of HCl acid in the gastric secretion). It responds to stimulation by histamine.

The Achlorhydria patients are of two types:

(i) Those who do not respond to histamine phosphate stimulation for the release of HCl.

(ii) Those who respond to histamine phosphate stimulation for the release of HCl in the stomach.

In either of the cases, the G.I. disturbances i.e. frequent bowel movement, mild diarrhoea, epigastric pain and sensitivity to spicy foods are the common symptoms. It is used to control the pH of the acidic stomach (pH 1.5-3.5). This condition is best treated by the administration of HCl acid.

Hypochlorhydria: Hypochlorhydria is a condition in which the stomach produces an abnormally low amount of hydrochloric acid (HCl). The acid is present but is insufficient for normal digestion and absorption of nutrients.

Achlorhydria: Achlorhydria is a condition in which there is complete absence of hydrochloric acid (HCl) secretion by the gastric parietal cells, even after stimulation.

2. Urinary Acidifiers: These are the drugs which are used to remove acidic urine from the body

or to maintain the pH of the urine. These acidifiers are widely used to cure some types of urinary tract infections.

For example: Many bacteria are grown badly in acidic urine as far as urine is concerned. Hexamine only acts as antiseptic when the urine is acidic. In acidic media, hexamine itself break up into ammonia and formaldehyde.

3. Systemic acidifiers: These are the drugs which are able to neutralise the alkaline body fluids, especially blood or to maintain the pH of all parts of the body. It is used to treat patients suffering from systemic alkalosis.

4. Acid: These are used as pharmaceutical aids in the preparation of medicaments, laboratory

quality control.

Ideal Characteristics of an Acidifier

- Produces the desired acidic environment effectively.
- Acts safely without causing excessive irritation.
- Maintains acid-base balance.
- Has minimal adverse effects.
- Is easy to administer and well tolerated.

Therapeutic Uses

- Treatment of hypochlorhydria and achlorhydria.
- Improvement of digestion in patients with low gastric acid secretion.
- Acidification of urine in selected urinary tract disorders.
- Enhancement of the absorption of certain minerals and medications.

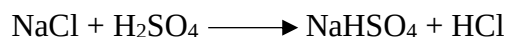
HYDROCHLORIC ACID

Molecular formula: HCl

Molecular Weight: 36.46

Synonym: Spirit of Salt, Muriatic acid

Preparation: 1. It can be prepared by the action of concentrated Sulphuric acid on Sodium Chloride and passing the liberated Hydrogen Chloride through water.



2. In this method, the hydrogen and chlorine obtained in the electrolysis of sodium chloride in the manufacture of caustic soda are burnt, preferably using quartz bunsen burners.

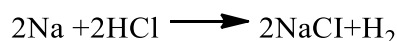


Properties:

1. It is nearly colourless clear and fuming liquid.
2. It possesses pungent odour.
3. It is soluble with water and alcohol.
4. It is a strong acid and attacks metals, forming the hydrochlorides with the evolution gas.

Chemical Properties:

1. It reacts with Sodium metal which results in the formation of sodium chloride and liberates hydrogen gas.



2. It is oxidised by strong oxidising agents liberating chlorine gas.



Storage: It is stored in well closed container of glass or other inert material at temperature not exceeding 30°C.

Uses:

- It is used in patients with **low gastric acid secretion** to restore normal stomach acidity and improve digestion.
- It is also used as replacement therapy in patients with **complete absence of gastric hydrochloric acid**, especially when prescribed by a physician.
- It helps to activate **pepsinogen to pepsin**, the enzyme responsible for protein digestion.
- Enhances the digestion of proteins in the stomach.
- It improves the absorption of **iron, calcium, and certain vitamins** by maintaining an acidic gastric environment.

SODIUM ACID PHOSPHATE

Sodium acid phosphate (NaH_2PO_4), is an **acidifying agent** used primarily as a urinary acidifier, mild saline laxative, and pharmaceutical buffering agent.

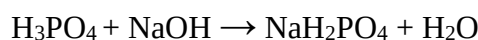
Molecular Formula: NaH_2PO_4

Molecular Weight: 119.98 g/mol (Anhydrous)

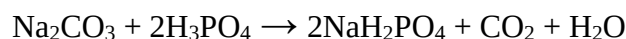
Synonyms: Sodium Acid Phosphate, Sodium Dihydrogen Phosphate, Monobasic Sodium Phosphate, Sodium Biphosphate

Preparation:

1. Sodium acid phosphate is prepared by the partial neutralization of phosphoric acid with sodium hydroxide. Since phosphoric acid is tribasic (contains three replaceable hydrogen ions), replacing only one hydrogen atom with sodium produces sodium dihydrogen phosphate (NaH_2PO_4), an acidic salt.



2. Sodium acid phosphate is prepared by the partial neutralization of phosphoric acid with sodium carbonate. During the reaction, carbon dioxide gas (CO_2) is evolved, producing effervescence.



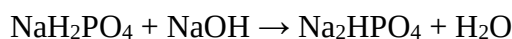
Properties: It is white crystalline powder or colorless crystals, Odorless, freely soluble in water, slightly acidic in reaction and hygroscopic (absorbs moisture from air).

Chemical Properties:

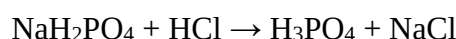
1. Sodium acid phosphate is slightly acidic in aqueous solution because the dihydrogen phosphate ion (H_2PO_4^-) can donate a proton (H^+).



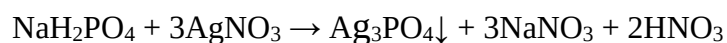
2. Sodium acid phosphate reacts with strong alkalis such as sodium hydroxide to form disodium hydrogen phosphate.



3. With strong mineral acids (e.g., hydrochloric acid), sodium acid phosphate forms phosphoric acid.



4. Sodium acid phosphate reacts with silver nitrate to form a yellow precipitate of silver phosphate.



Storage: It is stored in a well-closed, airtight container at room temperature. Must be Kept away from incompatible alkaline substances.

Uses:

- It helps to acidify urine in selected urinary tract disorders.
- It helps in relieving occasional constipation.
- It is also used in bowel cleansing before colonoscopy (specific formulations).
- In pharmaceuticals it is used as a urinary acidifier and mild saline laxative.
- It also helps in maintaining the pH of oral, injectable, and ophthalmic preparations.

ANTACIDS

These are the agent which neutralizes HCl acid in the body. If there is excessive secretion of HCl in a stomach is known as "**Hyperchlorhydria**" & if there less secretion of HCl in stomach is known as "**Hypochlorhydria**" although hyper or hypo it is not applicable for body mechanism but if there hyperchlorhydria it leads to minimize acid level & the drugs which neutralizes or minimizes acid level in the body is called as **Antacids**.

Antacids are the substance which are used to neutralize the gastric acidity. Acidity occurs due to excessive secretion of HCl in stomach due to various reasons. They produce sympathomimetic relief from pain, heart burns or by neutralizing the excess of hydrochloric acid.

E.g. aluminium hydroxide gel I.P.

The neutralizing capacity of an antacid is expressed in milliequivalents (mEq) of hydrochloric acid. Every antacid may have a total neutralizing capacity of atleast 5 mEq of HCl per dosage unit.

Antacids raise the pH of the gastric contents to above 3.5.

Antacids may be classified as:

Based on chemical Nature of Antacid properties:

Absorbable Antacids	Non-Absorbable Antacids
The absorbable antacids (Chemical Antacids) show the most rapid onset of action and provide faster relief of symptoms.	The non-absorbable antacids though less prone to cause a rebound effect.
However they may cause an "acid rebound".	Moreover as these antacids are more potent and effective in a semi liquid or liquid form than in a capsule or tablet.
Absorbable antacids inappropriate for patients afflicted with hypertension or kidney failure.	The usually high presence of aluminum and magnesium hydroxides in non-absorbable antacids can be effectively used to prevent significant stress ulcer bleeding in post-operative patients or those with severe burns.
Example: Sodium bicarbonate (baking soda), Magnesium oxide, Magnesium carbonates, Calcium carbonates.	Example: Aluminum phosphate, Aluminum hydroxide, Magnesium silicate, Magnesium hydroxide.

Based on pharmacological properties of Antacid

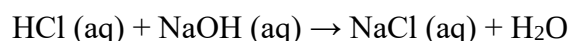
1. **Systemic (absorbable) antacid:** These are soluble, readily absorbable and capable of

producing systemic electrolytic alterations and alkalosis. Example: Sodium Bicarbonate.

2. **Non-systemic (Non-absorbable) antacids:** These are not absorbed to a significant extent and thus do not exert an appreciable systemic effects e.g. Aluminium salts, Magnesium salts and Calcium Carbonate.

Mechanism of antacid:

Antacids were developed based on the hydroxides and carbonates of the group II and III metals, as well as the bicarbonates of the alkali metals. All antacids contain at least one of the following metals: aluminum, calcium, magnesium, sodium, potassium, or bismuth. Antacids help neutralize excess acid produced in the stomach, i.e. the hydrogen ion concentration is reduced. Each antacid has a specific active ingredient. This ingredient whether metallic or non-metallic has a different effect on the gastric acid. They act similar to when an acid reacts with a hydroxide; a salt and water are produced as in the following equation:



Sodium Bicarbonate: $\text{HCl (aq)} + \text{NaHCO}_3 \text{ (aq)} \rightarrow \text{NaCl (aq)} + \text{H}_2\text{O} + \text{CO}_2$

Magnesium Compounds: $\text{HCl (aq)} + \text{Mg (OH)}_2 \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$

Aluminum Compounds: $\text{Al (OH)}_3 + \text{HCl} \rightarrow \text{AlCl}_3 + \text{H}_2\text{O}$

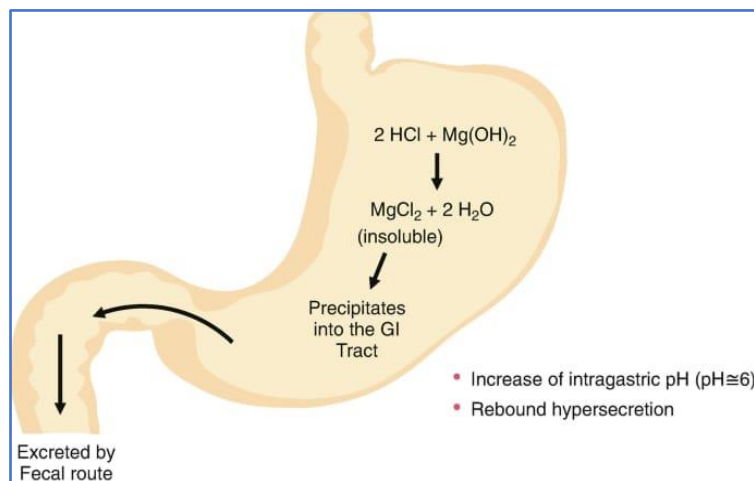


Fig. Mechanism of Antacids

Requirements for an ideal antacid

- It should be insoluble in water and should have fine particle size.
- The antacid should not be absorbable or cause systemic alkalosis.
- The antacid should not be a laxative or cause constipation.
- The antacid should exert its effect rapidly and over a long period of time.
- The antacid should buffer in the pH 4-6 range.

- The reaction of the antacid with gastric hydrochloric acid should not cause a large evolution of gas.
- The antacid should probably inhibit pepsin.

Combinations of Antacids:

Requirement of combinations of antacids therapy:

- **Systemic Antacid** leads to alkalosis, may worsen edema and congestive heart failure because of sodium ion load, thereby they are not frequently used.
- Whereas **non-systemic antacid** are more potent and effective as compare to systemic antacid, but they are insoluble and poorly absorbed systemically.
- In Magnesium salt, **Magnesium carbonate** is most water soluble and reacts with HCl at a slow rate, while
- **Magnesium hydroxide** has low solubility and has the power to absorb and inactivate pepsin and to protect the ulcer base.
- **Aluminium hydroxide** is a weak and slow reacting antacid. The aluminium ions relax smooth muscles and cause constipation.
- **Calcium carbonate** is a potent antacid with rapid acid neutralizing capacity, but on long term use, it can cause hypercalcemia, hypercalciuria and formation of calcium stone in kidney.

Every single compound among antacid have some side effect especially when used for longer period or used in elderly patients. To avoid certain side effects associated with antacids, combinations of antacids are used such as:

1. Aluminium Hydroxide + Magnesium Hydroxide (Most Common Combination)

Composition: Aluminium Hydroxide Gel and Magnesium Hydroxide

Why is this combination used?

Aluminium Hydroxide	Magnesium Hydroxide
Slow acting	Rapid acting
Causes constipation	Causes diarrhea
Long duration	Short duration

- Magnesium hydroxide provides rapid relief.
- Aluminium hydroxide provides prolonged action.
- Constipation caused by aluminium is balanced by the diarrhea-producing effect of magnesium.

2. Calcium Carbonate + Magnesium Hydroxide

- Calcium carbonate has a high acid-neutralizing capacity.
- Magnesium hydroxide provides rapid relief and reduces constipation.

Advantages: Having Fast onset, High neutralizing capacity, Balanced bowel effects.

Uses: In Heartburn, Acid reflux

SODIUM BICARBONATE

Sodium bicarbonate is a systemic antacid that rapidly neutralizes gastric hydrochloric acid. Because it is readily absorbed from the gastrointestinal tract, it provides quick relief from hyperacidity and heartburn. However, due to systemic absorption and adverse effects, it is not recommended for long-term therapy. Sodium bicarbonate is rarely used alone for long-term treatment because it is a systemic antacid that can cause acid rebound, metabolic alkalosis, and CO₂ production.

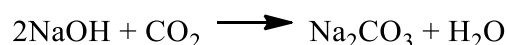
Molecular Weight: 84.01

Molecular formula: NaHCO₃

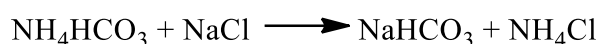
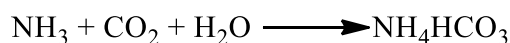
Synonyms: Sodium Hydrogen Carbonate, Baking Soda, Mitha Soda.

Preparations:

1. On small scale, it is prepared by passing CO₂ gas through a solution of sodium hydroxide.



2. **Solvay Process (Ammonia Soda Process):** Strong solution of Sodium Chloride containing a high concentration of ammonia is passed through a carbonating tower where it is saturated with CO₂ gas under pressure.



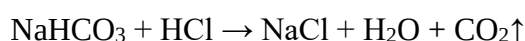
Ammonia and Carbon Dioxide react to form Ammonium Bicarbonate which further undergo decomposition to form Sodium Bicarbonate. The precipitated sodium bicarbonate is filtered. The crystals are washed with cold water to remove impurities. The crystals are dried at low temperature (below 60°C) because heating above this temperature causes decomposition.

Properties:

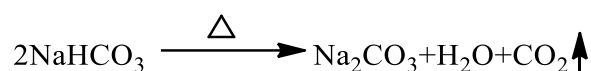
1. It occurs as white crystalline or amorphous powder.
2. It is having a saline taste.
3. Its solution is alkaline in nature.
4. It is freely soluble with water but practically insoluble in alcohol.

Chemical Properties:

1. On reaction with acids it neutralizes acids with evolution of carbon dioxide. Brisk effervescence due to CO₂ gas.



2. On heating, sodium bicarbonate decomposes.

**Assay:**

Weigh accurately about 0.6gm of sodium carbonate, previously dried



Dissolved in 50ml of water



Titrate with 0.5ml HCl using bromophenol blue as indicator.

Storage: Stored in a well-closed, airtight container at room temperature. Protect from moisture, heat, and carbon dioxide.

Uses:

- It is mainly used as electrolyte Replenisher.
- It is mainly used for its Acid Neutralizing properties.
- It is also find used as an antacid.
- It is used as local applicant for burns, insect bites etc.

ALUMINIUM HYDROXIDE GEL

Aluminium hydroxide gel is a **non-systemic antacid** widely used to neutralize excess gastric acid. It reacts slowly with hydrochloric acid in the stomach, providing prolonged relief from

hyperacidity without producing carbon dioxide. Since it is only minimally absorbed from the gastrointestinal tract, it has fewer systemic adverse effects than systemic antacids.

Chemical formula: $\text{Al}(\text{OH})_3$

Molecular Weight: 77.99

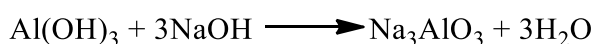
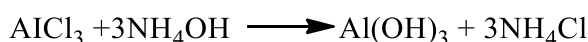
Synonym: Aluminium Hydroxide Powder, Aluminium Hydrated Powder It can be recognized into two ways

- (a) Aluminium Hydroxide Gel
- (b) Dried Aluminium Hydroxide Gel

(a) Aluminium Hydroxide Gel: It is white viscous suspension of Hydrated Aluminium Oxide with varying amounts of basic aluminium carbonate. It gets separated into the clear liquid on standing for some time. It exhibits suitable flavouring and antimicrobial agents. It has a pH between 5.5 and 8.0. The preparation may be sometimes having methyl oil, peppermint oil, glycerine, sucrose, saccharin etc. as flavouring and sweetening agents and sodium benzoate as a preservative.

Preparation:

1. When an Aluminium Salt such as Aluminium Chloride is treated with Ammonia or Sodium Carbonate, a white gelatinous precipitate of aluminium hydroxide is obtained.



After complete removal of CO_2 the precipitate Aluminium Hydroxide is filtered, washed thoroughly with hot water until it become free from sulphates ions. The precipitate may be suspended in the purified water to strengthen aluminium hydroxide gel.

2. It is prepared by adding a hot solution of potash alum slowly with constant stirring to hot solution of sodium carbonate. After complete removal of carbon dioxide, the precipitated aluminium hydroxide is filtered. It is washed thoroughly with hot water until it becomes free from sulphate ion and the precipitate is suspended in distilled water to the required strength.

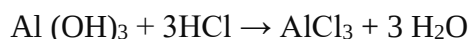


In the above preparation, the main precaution to be kept in mind is that the alum solution is added to the solution of sodium carbonate and not vice versa because that would yield a precipitate having alkali sulphate which would be difficult to wash.

In washing the precipitate of $\text{Al}(\text{OH})_3$ hot water but not boiling water should be used as the latter tends to decompose the aluminium hydroxide. It is to be remembered that a hydroxide is formed instead of a carbonate. The reason is that aluminium carbonate is unstable and it immediately gets hydrolysed to yield aluminium hydroxide and carbon dioxide.

Properties: It is a white viscous suspension. A clear liquid gets separated when it is kept standing for some time.

Aluminium hydroxide gel gives astringent aluminium chloride when it reacts with gastric hydrochloric acid. This results into nausea, vomiting and constipation.



Tests for purity: It has to be tested for alkalinity, ammonium salts, arsenic, chloride, sulphate and acid consuming capacity.

Test for chloride: It is carried out by dissolving 0.5 g of gel in 5 ml of dilute HCl followed by boiling and cooling and diluting the solution to 100 ml with water and taking 25 ml of diluted solution after filtration for carrying out the limit test for chloride.

Test for sulphate: It is carried out by dissolving 5 g of gel in 5 ml of dilute nitric acid, followed by heating. The solution is diluted after cooling with 200 ml of water. The solution is mixed well and filtered, if necessary. 10 ml of the filtrate is taken and after adding 2 ml of HCl the solution is used for carrying out limit test for sulphate and the test should comply.

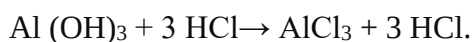
Assay: Nearly 5 g of substance is accurately weighed and taken in a flask. To this 3 ml of hydrochloric acid is added. The solution is now warmed on a water bath. After cooling, this is transferred to a 100 ml volumetric flask and the volume is made up to 100 ml.

Now 20 ml of the solution is taken from the volumetric flask into a conical flask and exactly 40 ml of 0.05 disodium edetate is added to it, followed by about 80 ml of water and a few drops of methyl red solution. To this 1N sodium hydroxide solution is added to neutralise this solution. This can be recognised and be used as the latter by change of colour from red to yellow. Now the flask is warmed on a water bath for about ½ hour. To this 3 g of hexamine is added. Also, the 0.5 ml of xylenol orange solution is added to it as an indicator. The mixture is now filtered with a standard 0.05 M lead nitrate solution until a violet colour appears at the end point due to the formation of lead xylenol orange complex.

Factor: Each ml of 0.05 M disodium EDTA is equivalent to 0.002549 g of Al_2O_3 .

Storage: It is to be stored in well-closed containers and should not be allowed to freeze. For attractiveness it is usually dispensed in blue or amber coloured bottles.

Uses: Aluminium hydroxide gel is a very effective slow-acting antacid.



It does not get absorbed in alimentary canal and does not produce carbon dioxide. It is widely used in treatment of intestinal toxemia and hyperchlorhydria. It is able to neutralise gastric hydrochloric acid and causes absorption of toxins, and gases. It does not cause any systemic alkalosis.

(b) Dried Aluminium Hydroxide Gel:

Properties: It is not a typical gel but is a white, odorless, tasteless, amorphous powder. It is insoluble in water and alcohol but soluble in dilute mineral acids & solution of fixed Alkali

Hydroxides. It forms gel on prolonged contact with water. It absorbs certain acids and CO₂. It has a pH between 5.5-8.0.

One major drawback of gel is that of a loss of antacid properties on aging.

Tests for purity: It is tested for ammonium salts, heavy metals, chloride, sulphate and acid consuming capacity.

The **test for chloride** is performed by dissolving 0.5 g of the gel in 10 ml of dilute nitric acid followed by boiling and cooling and diluting it with water to make the volume 100 ml. The solution filtered and 25 ml of the filtrate should comply with the limit test for chloride.

The **test for sulphate** is carried out in the same way as described for chloride except that in this test 5 ml of dilute HCl has been used (instead of 10 ml of dilute nitric acid in chloride test).

Assay: An accurately weighed (0.4g) of sample is dissolved in a mixture of 3.0 ml of hydrochloric acid and 3.0 ml of water by warming on a water bath. Rest of the procedure remains same as described under "Aluminium hydroxide gel." Each ml of 0.05 M disodium edetate = 0.002549 g of Al₂O₃.

Uses: It finds use as an antacid in doses of 0.5 to 1.0 g per day.

Stability: Heating to temperatures much in excess of 30°C results in gradual dehydration and loss of therapeutic value. Partial loss of neutralising activity may occur during tableting.

Storage: The Gel should be stored at temperature not exceeding 25°C, it should not be allowed to freeze. The Dried Gel should be stored in airtight containers at a temperature not exceeding 25°C.

Other pharmaceutical uses: Dried aluminium hydroxide gel is used externally as mild astringent and desiccant. It is infrequently used in the treatment of diarrhoea and cholera and as protective, externally as a dusting powder for desiccating foul wounds etc. It is a constituent of some foot powders. In silicosis therapy, it is given by inhalation.

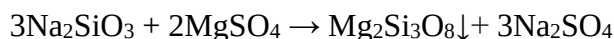
MAGNESIUM TRISILICATE

Magnesium trisilicate is a non-systemic antacid used for the treatment of hyperacidity, gastritis, peptic ulcer disease, and gastroesophageal reflux disease (GERD). It reacts slowly with gastric hydrochloric acid to neutralize excess acid and forms colloidal silica, which coats and protects the gastric mucosa. It provides slow but prolonged antacid action and is often combined with aluminium hydroxide.

Molecular formulae: 2 MgO.3SiO₂. xH₂O (molecular weight is not fixed, because magnesium trisilicate is a hydrated compound with variable water content. Therefore, no definite molecular weight is assigned in pharmacopoeias).

Synonym: Hydrated magnesium silicate

Preparation: Magnesium trisilicate is prepared by the reaction of sodium silicate with a soluble magnesium salt, followed by washing, drying, and pulverizing. Aqueous solutions of sodium silicate and magnesium sulphate was prepared. These two solutions are mixed with continuous stirring and white gelatinous precipitate of hydrated magnesium trisilicate forms. Precipitates are filtered and washed to remove sodium sulphate and other soluble impurities.

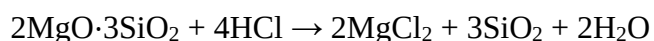


Properties: It is White, fine, light powder, odorless and tasteless. It is practically insoluble in water and alcohol.

Chemical Properties:

1. Magnesium trisilicate is a weakly basic inorganic compound. It neutralizes excess gastric acid slowly.

2. **Reaction with Hydrochloric Acid:** Neutralizes gastric acid and Forms a protective silica gel.



(In aqueous media, hydrated silica/colloidal silica is formed.)

3. Produces colloidal silica, which forms a protective coating over the gastric mucosa and ulcer surface.

Test for purity: It has to be tested for As, Fe, heavy metals, chloride, sulphate, acid absorption and loss on ignition.

Storage: It is kept in tightly closed containers.

Uses: It finds use as an antacid and adsorbent. It reduces gastric hyperacidity and pain, in gastric and duodenal ulcers. In larger doses it is able to induce diarrhoea. It finds use as an emulsifying agent for oils when used in proper proportions.

Magnesium trisilicate being insoluble in water has advantage over other carbonate and hydroxide type antacids of alkaline earth, that it neutralises the excess acidity of stomach, without causing the alkalinisation of the system. When magnesium trisilicate is ingested, the silicon dioxide associated gets into colloidal form and acts as a protective on to the ulcers and thus prevents further attack of acid on peptic ulcers.

AGENTS PROMOTING BOWEL MOVEMENTS

Agents promoting bowel movements are drugs that facilitate the passage of stool by increasing intestinal motility, softening the feces, or increasing the water content of the intestinal contents. These agents are collectively known as **laxatives**, **purgatives**, or **cathartics** and are primarily used to treat constipation and to empty the bowel before diagnostic or surgical procedures.

Laxatives: Mild agents that produce soft, formed stools and are used to relieve constipation.

Purgatives/Cathartics: Stronger agents that produce rapid and complete evacuation of the bowel.

Cathartics may be defined as those drugs which bring about defecation. They are beneficial in constipation and for expulsion of intestinal parasites. They may also be given for clearing bowels before surgery.

Purgatives are also cathartics which act similarly but are generally mild in their nature of action. **Laxatives** are the mild type of purgatives. Both these bring about the same effect but vary in nature and mechanism of action.

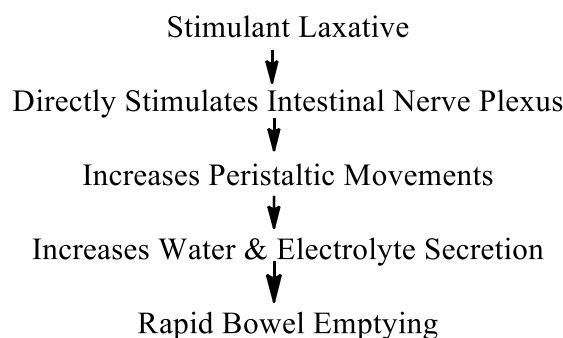
Laxatives, cathartics and purgatives act by retaining fluid in the bowel. These may be administered by oral route (suspension or by powder) or by rectal route (enema or suppository).

Cathartics are the drugs which are able to bring about defecation. Purgatives act similarly but are generally mild in their nature of action; whereas laxatives are the mild type of purgatives. They give rise to the same effect but vary in nature and by mechanism.

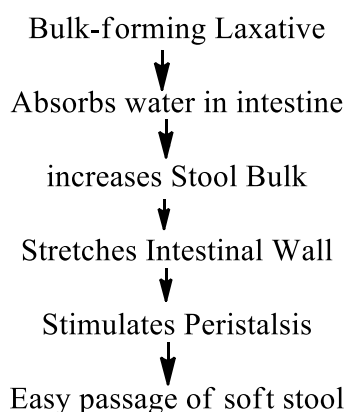
In normal habits, peristalsis causes defecation. The peristaltic waves are able to stimulate bowel and relieve its contents. The peristaltic motion normally take place about three to four times a day. By ignoring the urge to defecate by voluntary or by psychological lead to constipation. **Constipation** can also be brought about by many factors like weakness of intestine, intestinal spasm, injury or use of certain drugs and diet etc. In constipation fecal material becomes dry and hard. Use of laxative or purgative (lubricants) type provides relief in constipation by elimination of bowel contents.

Classification of Agents Promoting Bowel Movements

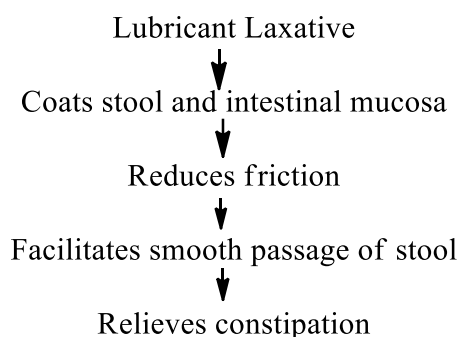
(1) Stimulants: These are the drugs or chemicals which act by local irritation on intestinal tract and bring about stimulation of peristaltic activity. As they act directly on intestine and stimulate peristalsis they are termed as stimulants. Drugs like senna, rhubarb, cascara, podophyllum, castor oil, aloe, bisacodyl etc. belong to this class. These are mainly used for short-term treatment of constipation and bowel evacuation before diagnostic procedures.



(2) Bulk purgatives: These are the agents which are able to increase bulk of intestinal contents. These are cellulose or non-digestible type of materials which swell considerably when wet and because of increased bulk stimulate peristalsis. Examples of bulk purgatives are methylcellulose, sodium CMC, gum, isabgol etc. They are used in the case of chronic constipation and Irritable bowel syndrome (IBS).



(3) Lubricants: In constipation, contents of intestine become hard because of absorption of water by body, there results difficulty in clearing of bowels. These coat the stool and intestinal wall with a lubricating film, facilitating easy passage of feces. Substances such as liquid paraffin, glycerin, mineral oils etc. act as lubricants and cause smooth clearance of the fecal material. These are used in Constipation and painful defecation.

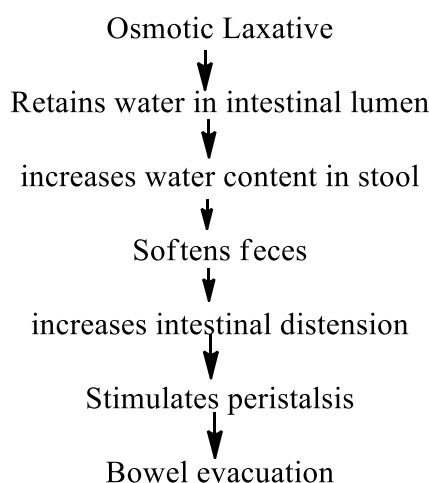


(4) Saline cathartics (osmotic laxatives): These act by increasing the osmotic load of intestine by absorbing large quantity of water and thereby stimulate peristalsis. Poorly absorbable

cations like calcium, magnesium and anions like phosphate, sulphate, tartrate are contributing to this effect. The saline cathartics are water soluble mainly inorganic chemicals and they are taken with plenty of water. This is helpful in restricting excessive loss of body fluid and reduces nausea and vomiting.

The saline laxatives are relatively free from side-effects when taken for brief periods. Patients on low sodium diet should not use the sodium containing saline laxatives. They may be administered by oral route (suspension or powder) or by rectal route (enema or suppository).

These cathartics are taken in the form of suspension, tablet, or in other suitable formulations. Examples of saline laxative and cathartic agents are different magnesium salts such as magnesium hydroxide, magnesium sulphate, etc. and tartrate salts of sodium and potassium. The absorption of these drugs is very poor. Their action is mainly attributed to their osmotic property in intestinal lumen.



MAGNESIUM HYDROXIDE

Milk of magnesia is a suspension having not less than 7 per cent w/w and not more than 8.5 per cent w/w of magnesium hydroxide $\text{Mg}(\text{OH})_2$, in purified water. It may contain one or more suitable preservatives. It is also called cream of magnesium hydroxide mixture.

Synonyms: Milk of magnesia

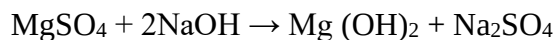
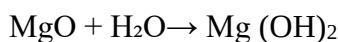
Molecular formula: $\text{Mg}(\text{OH})_2$

Molecular weight: 58.31

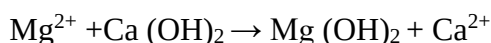
Preparation:

1. Although the preparation is having magnesium hydroxide, it is not obtained by suspending magnesium hydroxide but by reacting sodium hydroxide with magnesium sulphate. Light magnesium oxide is mixed with solution of sodium hydroxide to get a smooth cream. It is now diluted with water and the suspension is poured in thin stream into a solution of magnesium sulphate stirring continuously. The precipitate is allowed to settle. Now the upper clear liquid is removed by decantation, the residue is transferred on a calico filter. Now the residue is

washed with water until it becomes free from sulphate ions. The precipitate is mixed with sufficient water to get the required volume.

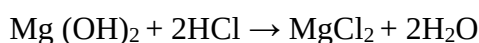


2. On a commercial scale, $\text{Mg}(\text{OH})_2$ is prepared by treating seawater with lime $\text{Ca}(\text{OH})_2$.



Properties: It occurs as white, odourless powder. It is soluble in dilute acids and practically insoluble in ethanol and water.

Chemical Properties: It is having ability to neutralize acids because it is a weak inorganic base. It provides hydroxide ions (OH^-), which react with hydrogen ions (H^+) from gastric hydrochloric acid, thereby increasing the pH of the stomach contents.



Assay: An accurately weighed amount of sample (5 ml) is taken in a flask. To it 25 ml of 1 N sulphuric acid is added. Now the excess of acid is back titrated with 1 N sodium hydroxide using methyl red as an indicator.

Each ml of 1 N sulphuric acid = 0.02917 g of $\text{Mg}(\text{OH})_2$.

Test for purity: It is tested for soluble alkalies, soluble salts, carbonates and acid insoluble matter besides As, Ca and heavy metals.

Storage: It is stored in tightly closed containers. It should not be kept in a cold place.

Uses:

- It is used as a laxative to relieve constipation.
- It is also used to treat gastrointestinal ailments such as heartburn, general upset stomach, or feelings.
- As it has alkaline reaction it is used as alkaline mouth wash but due to alkalinity it causes liberation of alkaloids from their solutions.

SODIUM ORTHOPHOSPHATE

Sodium orthophosphate is the trisodium salt of orthophosphoric acid. It is a strongly alkaline inorganic compound that is mainly used as a saline cathartic (osmotic laxative) to promote bowel evacuation. It is also used as a buffering and alkalizing agent in pharmaceutical formulations and laboratory preparations.

Chemical Formula: Na_3PO_4

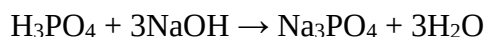
(Commonly available as $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$, trisodium phosphate dodecahydrate.)

Molecular Weight: Anhydrous: 163.94 g/mol and Dodecahydrate ($\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$): 380.12 g/mol

Synonyms: Sodium Orthophosphate, Trisodium Phosphate (TSP), Tribasic Sodium Phosphate, Trisodium Orthophosphate

Preparation:

1. Sodium orthophosphate is prepared by complete neutralization of phosphoric acid with sodium hydroxide. An aqueous solution of phosphoric acid was prepared and sodium hydroxide solution added slowly with continuous stirring. Sodium hydroxide is added until complete neutralization of all three acidic hydrogen atoms occurs. Solution is concentrated and crystals of sodium orthophosphate was separated by filtration.

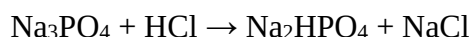


Properties: It is white crystalline powder or colorless crystals, odorless, freely soluble in water and insoluble in alcohol. It is strongly alkaline in aqueous solution and hygroscopic (absorbs moisture from air).

Chemical Properties:

1. Sodium orthophosphate is a strongly alkaline salt. Its aqueous solution has a pH of about 11–12.

2. It reacts with mineral acids to form disodium phosphate, monosodium phosphate, or phosphoric acid, depending on the amount of acid added.



Assay: The solution of the salt (6 g in 100 ml of water) is titrated with 0.5 N H_2SO_4 using bromocresol green as indicator to its green colour indicative of pH 4.5. The results may be expressed on the basis of the salt dried at 130°C ; So it is neutralised to sodium acid phosphate.

Or Each ml of 0.5N H_2SO_4 is equivalent to 0.07098 g of Na_3HPO_4

Storage: It is stored in tightly closed containers.

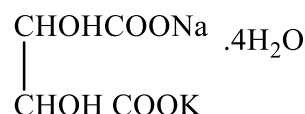
Uses:

- It is used as an saline cathartic (osmotic laxative) for constipation.
- For Bowel cleansing before surgery, colonoscopy, or radiological procedures (in appropriate formulations).
- In pharmaceuticals it is used as an buffering agent, Alkalinizing agent, pH adjuster in pharmaceutical preparations.

- In laboratories it is used in the preparation of phosphate buffer solutions and Analytical reagent.

SODIUM POTASSIUM TARTARATE

Molecular Formulae:



Molecular weight: 28.22

Synonym: Rochelle Salt

It is having not less than 99.0 per cent and not more than 104.0 per cent of sodium potassium tartarate.

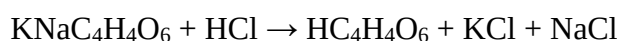
Preparation: It is obtained by neutralizing a solution of sodium carbonate with potassium bitartrate. The solution is boiled for some time and then allowed to stand at 60°C for the completion of reaction and the neutrality adjusted. Carbon dioxide is slowly evolved. The solution is filtered, concentrated to crystallisation.



As it effloresces slightly in warm dry air, the crystals are often coated with a white powder.

Properties: It is colorless transparent crystals or white crystalline powder, odorless having saline, cooling taste. It is freely soluble in water and insoluble in alcohol. Efflorescent on exposure to dry air.

Chemical Properties: 1. It reacts with strong acids to liberate tartaric acid.



2. On strong heating, it decomposes with the evolution of gases and leaves carbonaceous residue.

Identification:

(1) When heated the salt emits an odour of burning sugar and leaves a residue which is alkaline to litmus papers and gives effervescence with acids.



(2) The salt gives characteristic reactions of sodium and potassium.

Tests for purity: It is tested for acidity and alkalinity, As, Fe, heavy metals, chloride, sulphate and loss on drying.

Assay: An accurately weighed quantity (about 2 g) is heated in a silica crucible until carbonised. The residue is boiled with 50 ml of water and 15 ml of 0.5 N sulphuric acid. The solution is filtered and the residue washed. The filtrate and washings are titrated for an excess of acid with 0.5 N sodium hydroxide using methyl orange as an indicator.

Each ml of 0.5 N H_2SO_4 = 0.07055 g of $\text{KNaC}_2\text{H}_2\text{O} \cdot 4\text{H}_2\text{O}$

Action and uses: Its action is due to tartrate ions and its mechanism is similar to that of phosphate ions. It is administered in solution for its saline cathartic action. Its usual dose is 10 g. Children may be given half the adult dose. It is an ingredient of compound effervescent powder. It is also used as food additive.

ANTIMICROBIALS

Antimicrobial agents (disinfectant and antiseptic) are chemical substances that destroy microorganisms or inhibit their growth (bacteria, fungi or protozoans) thereby preventing or treating infections. These agents are widely used in medicine, pharmacy, surgery, public health, water purification, and food preservation. Microorganisms such as bacteria, fungi, viruses, protozoa, and algae can cause various infectious diseases. Antimicrobial agents help control these organisms either by killing them (microbicidal action) or by preventing their multiplication (microbiostatic action).

An ideal antimicrobial agent should possess broad-spectrum activity, act rapidly at low concentrations, remain stable during storage, be non-toxic to human tissues, be economical, and should not interfere with the healing process. The effectiveness of antimicrobial agents depends on several factors, including concentration, duration of contact, temperature, pH, presence of organic matter, and the type of microorganism.

In Pharmaceutical Inorganic Chemistry, antimicrobial agents such as Potassium Permanganate, Boric Acid, Hydrogen Peroxide, Chlorinated Lime, and Iodine are commonly studied because of their antiseptic and disinfectant properties.

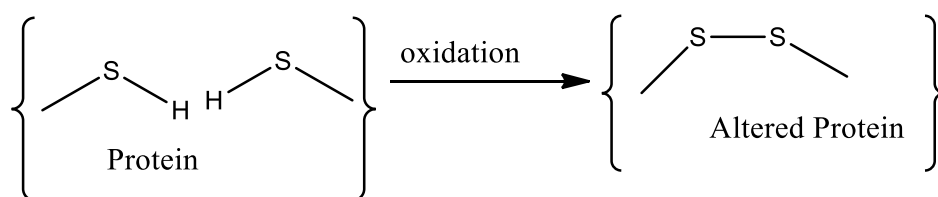
Mechanism of Action of Antimicrobial Agents

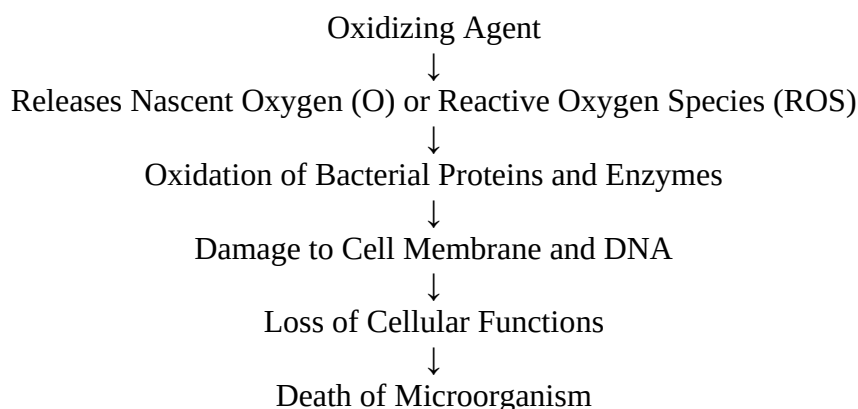
Pharmaceutical inorganic antimicrobial agents primarily function via oxidation, halogenation, or protein precipitation/binding. These non-selective mechanisms target structural and enzymatic proteins, destroying microorganisms like bacteria and fungi by disrupting their vital biochemical processes and cell architecture. The mechanisms are broken down into three primary categories:

1. Mechanism of Oxidizing Agents

Examples of oxidizing agents: Potassium Permanganate (KMnO_4), Hydrogen Peroxide (H_2O_2), Chlorinated Lime.

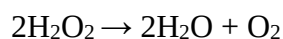
Principle: Oxidizing agents release nascent oxygen (O) or reactive oxygen species (ROS), which oxidize vital components of microbial cells. This involves the release of nascent oxygen or reactive oxygen species, which irreversibly alter essential functional groups in microbial proteins and enzymes (such as oxidizing sulfhydryl (-SH) groups to form disulfide (-S-S-) bonds). This alters protein structure and causes enzyme malfunction.





The antimicrobial agent comes in contact with the microorganism. It releases oxygen or reactive oxygen species. The liberated oxygen is highly reactive. Oxygen oxidizes proteins, lipids, enzymes and nucleic acids of microorganisms. Cell membrane becomes damaged and enzymes become inactive. The microorganism cannot carry out respiration and metabolism. The microorganism dies.

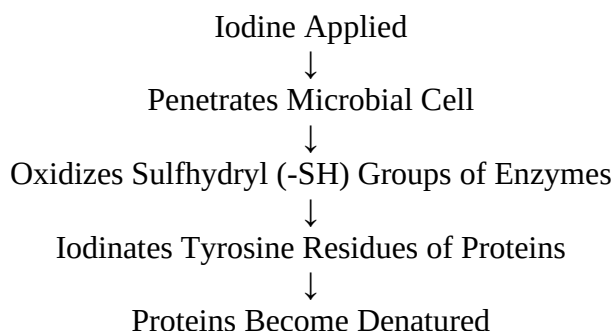
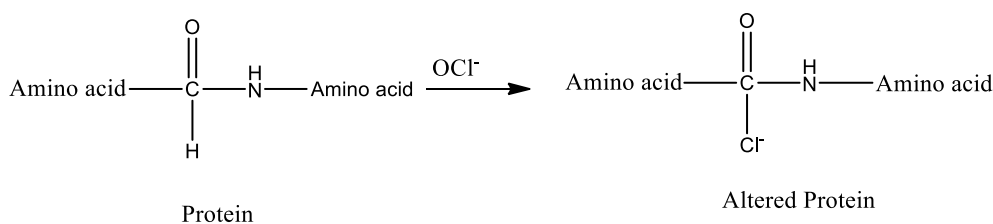
Example: Hydrogen peroxide

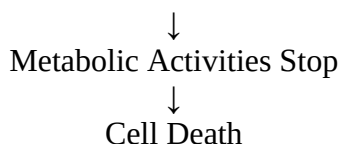


2. Mechanism of Halogenating Agents

Example: Iodine

Principle: Halogens react with amino acids and enzymes present in microorganisms, forming stable complexes that inactivate enzymes and destroy microbial cells. Iodine kills microorganisms by oxidation and iodination (halogenation) of proteins and enzymes. Iodine combines with tyrosine residues of proteins and oxidizes sulfhydryl (-SH) groups of enzymes.



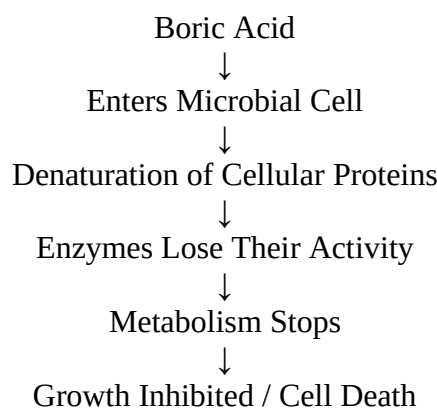


Iodine enters the bacterial cell. It combines with proteins and amino acids. Essential enzymes become inactive. Protein synthesis and metabolism stop. The microorganism dies rapidly.

3. Mechanism of Protein Denaturing Agents

Example: Boric Acid

Principle: These agents denature (coagulate) microbial proteins. Denatured proteins lose their biological activity, causing disruption of metabolic functions and death of microorganisms.



Boric acid alters the three-dimensional structure of proteins and make conformational changes in microbial protein. Enzymes lose their biological activity. Cellular metabolism stops. Growth of microorganisms is inhibited.

4. Damage to Cell Membrane

Some antimicrobial agents alter membrane permeability, causing leakage of intracellular components such as potassium ions, amino acids, nucleotides, and enzymes. Loss of cellular contents ultimately causes microbial death.

5. Inhibition of Essential Enzymes

Many antimicrobial agents inhibit enzymes required for respiration, energy production, and biosynthesis. Blocking these enzymes prevents normal metabolism and cell growth.

Classification of Antimicrobials:

1. Antiseptics:

These are substances that are able to kill or prevent the growth of micro-organisms. This term is specific for preparations which are to be applied to living tissues. Antiseptic agents oppose the sepsis, putrefaction or decay of the damaged or exposed tissue by inhibiting microbial

multiplication and metabolic activities or by killing the pathogenic micro-organisms. An ideal antiseptic should destroy bacteria, spores, fungi, viruses or any other infective agent without causing any harm to the tissues of the host. They can be applied to almost all tissues of the body and may be used in the form of mouth washes, soaps, deodorants, throat and nasal sprays and vaginal douches. In general, all antiseptics are protein denaturants and act on enzymes in the bacteria. This accounts for the reduced effectiveness of most antiseptics in serum, blood or pus.

For e.g: Iodine, Boric acid.

2. Disinfectants: These are the substances that prevent infection by the destruction of pathogenic micro-organisms. These are generally used with reference to the substances applied to inanimate objects (non-living).

Disinfectants are widely used for home and hospital sanitation. They are bactericidal and rapidly produce irreversible lethal effects. Disinfection may be accomplished by heat, irradiation or chemicals. They are non-selective and destroy non-pathogens as well. They could be applied only to inanimate objects. All disinfectant solutions undergo deterioration under storage and elevated temperature conditions. Some chemical disinfectants are too irritant and corrosive to the skin or tissues.

For e.g: Disinfection of surgical instruments, urine containers, floors etc.

Common example of disinfectants are Cresol and phenol.

3. Germicides:

These are substances which kill micro-organisms. More specific terminology like 'bactericide' (against bacteria), 'fungicide' (against fungi), 'virucide' (against virus) etc. denotes exact action.

4. Bacteriostatics:

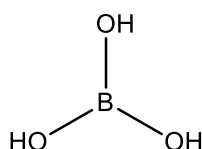
These are substances which primarily function by inhibiting the growth of bacteria. Thus, bacteriostatic drugs or agents do not kill but arrest the growth of bacteria.

5. Sanitizers:

Disinfectants that are used to maintain general public health standards, are termed as sanitizers. Sanitation is mainly concerned with cleaning or washing away the organic matter (e.g., saliva, mucous etc.). A germicidal agent is an anti-infective agent having power to kill the micro-organisms. Many agents at higher concentrations are able to exhibit germicidal activity. This concentration should not cause local cellular damage. Similarly, upon topical application, if absorbed, it should not give rise to systemic toxicities.

An antimicrobial agent should possess the following characteristics:

- (i) It should possess antiseptic or germicide activity and not bacteriostatic activity. If the micro-organisms do not get killed, they may resume growth and bring about infections.
- (ii) It should have rapid onset and sustained activity. This will be able to reduce incidence of resistance.
- (iii) It must possess good therapeutic index indicating usefulness in the concentration employed.
- (iv) It should not cause local cellular damage or should not interfere with body defenses.
- (v) It should show no systemic toxicity from topical applications.
- (vi) It should have in general broad spectrum of activity against bacteria, fungi, protozoa, virus etc.
- (vii) The topical antimicrobial agent should have favourable lipid- water distribution coefficient so that its effectiveness has been best.

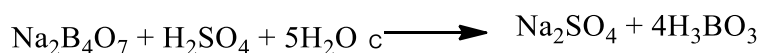
BORIC ACID**Molecular Formulae:** H_3BO_3 **Molecular weight:** 61.83**Synonym:** Boracic acid, Hydrogen borate, orthoboric acid

It is having not less than 99.5 per cent of H_3BO_3 which is calculated with reference to the substance and dried over sulphuric acid for five hours.

Occurrence: Free boric acid occurs in sea water, many plants and nearly all fruits. So far, its large natural source has been in the combined form as, for example, resonite and borax

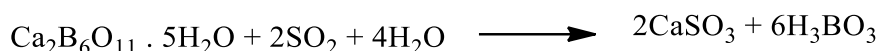
Preparation: Boric acid is prepared from native borax and from borates by reacting them with hydrochloric or sulphuric acid.

(1) In the laboratory, boric acid is obtained by adding a mixture of concentrated H_2SO_4 and water (1 : 5) to a boiling solution of borax (60 g in 160 ml of water).

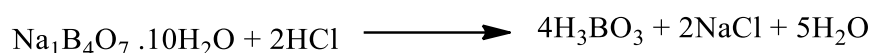


The solution is filtered and kept aside for crystallisation. The crystals of boric acid are separated and then washed until they become free from sulphate ions. Finally, they are dried at room temperature

(ii) Commercial Method: Boric acid is prepared commercially by decomposing certain naturally occurring borates, such as colemanite, resonite, borax etc. For example, powdered colemanite is suspended in boiling water and the suspension is then treated with sulphur dioxide gas to liberate boric acid.



When the solution is allowed to cool, acid crystallises out. When borax is treated with HCl, a high grade of medicinal boric acid is obtained.

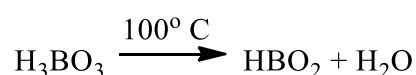


As HCl is volatile, residual traces of HCl are not left on the crystal surfaces when dried in air.

Properties: Boric acid is a solid which is available in three forms: Colourless, odourless pearly scales; Six-sided triclinic crystals; and White odourless powder, which is unctuous to touch. It is odourless with slightly acidic and bitter taste and unctuous touch.

It is stable in air, and is having a density of 1.46. The scale and crystalline forms have been most suitable, for preparing aqueous solutions, because the powder tends to float on top of water. However, the powder has been found to be very useful in dusting powders and ointments.

Boric acid is a weak acid. Its $\text{pK}_a = 9.19$ for the ionisation of the first proton at 25°C . Heating orthoboric acid to certain temperatures, yields various dehydration products. For example, boric acid on heating to 100°C loses one molecule of water, to give metaboric acid HBO_2 .



Heating to approximately 160°C , causes a further loss of water from metaboric acid to produce tetraboric acid, $\text{H}_2\text{B}_4\text{O}_7$

Solubility: It is soluble in water or alcohol, glycerin, boiling water and boiling alcohol.

Assay: It is assayed by a titrimetric method.

An accurately weighed quantity of boric acid (2 g) is dissolved in a mixture of 50 ml of water, and 100 ml glycerine previously neutralised to phenolphthalein. Now this solution is titrated with 1 N NaOH using phenolphthalein as an indicator.

Each ml of 1 N NaOH = 0.06183 g of HBO_3

It is assayed by titrimetric method. Being a very weak acid, it cannot be directly titrated accurately with strong alkali. When it is dissolved in a mixture of water and glycerine or mannitol, it behaves like a strong monobasic acid (i.e., glyceroboric acid) and then it can be titrated with alkali using phenolphthalein as an indicator.

Pharmaceutical uses: Boric acid is a local anti-infective and is used in dusting powders, local antiseptic creams, ointments, lotions etc applied to skin or mucous or eye. Aqueous solutions have been used as mouth washes, eye lotions, skin lotions and as douches for irrigating the bladder. It possesses weak bacteriostatic and fungistatic properties.

Its solutions are not irritant and are hence used for washing the eyes. Its 1.9% solution water is iso-osmotic with serum. It is also used in dusting powders after trituration with some other inert materials. It is toxic when taken internally and is absorbed from gastro-intestinal tract and from broken skin.

Storage: It is preserved in a well-closed container.

POTASSIUM PERMANGANATE

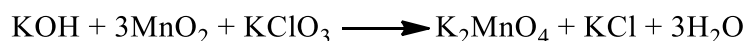
Molecular Formulae: KMnO_4

Molecular weight: 158.0

Synonym: Permanganate of Potash or Candy's crystals.

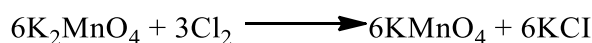
It is an inorganic compound having not less than 99.0% of KMnO_4 .

Preparation: On a large scale, potassium permanganate is prepared by mixing a solution of KOH with powdered manganese oxide and potassium chlorate. The mixture is boiled, evaporated to yield the residue which is heated in iron pans until it has acquired a paste consistency.



Potassium manganate

Potassium manganate (green) so formed is extracted with boiling water and a current of chlorine, CO_2 or ozonised air is passed into the liquid until it gets converted to permanganate. The MnO_2 formed is removed continuously so as to prevent its breaking down to the manganate.

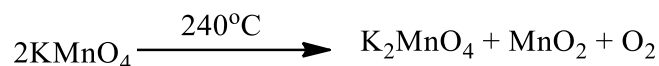


When carbon dioxide is passed through the solution in place of chlorine, only two-third of manganate gets converted into KMnO_4 . One third is converted into MnO_2 .

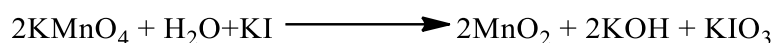


The solution of KMnO_4 , is drawn off from precipitate of MnO_2 , which is then concentrated and crystallised. The crystals are then centrifuged and dried.

Properties: It occurs as odourless dark purple or almost black prismatic crystals or granular powder. It has a sweet and astringent taste. It decomposes with a risk of explosion, in contact with certain organic substances. It has specific gravity of about 2.703. It is stable in air. It has a soluble in water. When it is heated, it decomposes at a high temperature of about 240°C .



Alkaline or neutral solution of potassium permanganate is able to oxidize iodide to iodate.



In acidic medium iodine gets liberated from iodates.

Uses: It finds use in the treatment of urethritis. It possesses oxidizing properties and oxidizes proteins and other bioorganic substance. It has the capability to destroy the poison and prevents absorption. Its solutions are used to clean the ulcer or abscesses, as wet dressings and in baths in eczematous condition. It finds use as an antidote in the case of poisoning by barbiturates, chloral hydrate and many alkaloids.

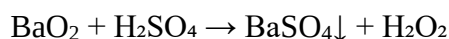
HYDROGEN PEROXIDE

Chemical Formulae: H_2O_2

Molecular weight: 34.016

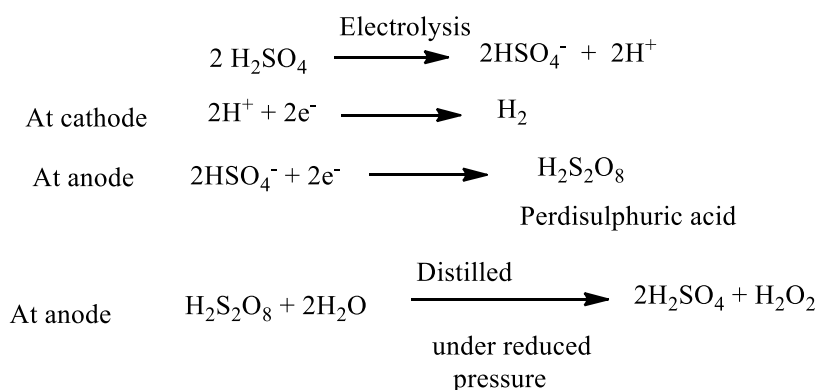
It is an aqueous solution of hydrogen peroxide. It is having not less than 6 per cent w/w of H_2O_2 , which is corresponding to about 20 times its volume of available oxygen.

Preparation: (1) It is obtained by adding a thick paste of barium peroxide in ice cold water to a calculated quantity of ice cold dilute sulphuric acid. The insoluble barium sulphate is filtered off.



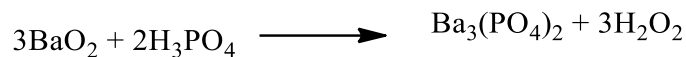
The yield of H_2O_2 is 10-20 per cent.

(2) It is also manufactured by the electrolysis of ice cold 50 percent sulphuric acid. Perdisulphuric acid is formed which on distillation under reduced pressure gives H_2O_2 .

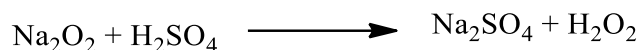


The yield of H_2O_2 is 30 per cent. The distillate containing H_2O_2 is analysed and is adjusted to the required strength.

(3) It is also obtained by decomposing barium peroxide with phosphoric acid or by-passing carbon dioxide through a suspension of barium peroxide in water.



From sodium peroxide: It is also obtained by treating sodium peroxide with dilute H_2SO_4 at low temperature. Sodium sulphate crystallises out and H_2O_2 is distilled under 10 mm pressure.



Properties: Hydrogen peroxide is clear, colourless syrupy liquid. It is odourless or may have an odour resembling to that of ozone unstable liquid. It has a specific gravity of about 1.463 at 0°C . It is a strong oxidizing agent. It is soluble with water from which it can be extracted with solvent ether. It rapidly decomposes in contact with oxidizable organic matter and with metals.

Assay: Hydrogen peroxide and acidified potassium permanganate, both are oxidising agents. These two oxidising agents reduce one another with the evolution of gaseous oxygen. Hydrogen peroxide reduces KMnO_4 solution and causes its decolouration. At the end point, excess drops of KMnO_4 gives pink colour. Potassium permanganate itself acts as an indicator.

The assay of hydrogen peroxide is carried out by the permanganate method. 10 ml of the sample is diluted to 250 ml in a volumetric flask with purified water. To 25 ml of this solution, 10 ml of 5 N sulphuric acid is added. Then, the contents are titrated with 0.1 N potassium permanganate solution, until a faint pink colour is obtained.

Each ml. of 0.1 N KMnO_4 = 0.001701 g of H_2O_2 .

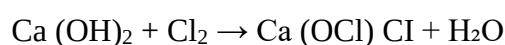
Storage: H_2O_2 is not stored in glass bottles since the alkali metal oxides present in glass catalyse its decomposition. It is stored in paraffin wax coated with glass, plastic or teflon bottles. Small amounts of acid, glycerol, alcohol, acetanilide often used as stabilizers to check its decomposition.

Uses: It acts as an antiseptic and a germicide and hence is used for cleaning cuts and wounds. It is used for bleaching delicate articles like wool, hair, feather, ivory etc. It is used as an aerating agent in production of sponge rubber. It is used as an antichlor. It finds use in deodorants. It is also used for cleaning ears and removing the surgical dressing. It is an effective antidote for phosphorous and cyanide poisoning.

CHLORINATED LIME**Chemical Formulae:** $\text{CaOCl}(\text{Cl})\text{H}_2\text{O}$ **Synonym:** Bleaching Powder

It is having not less than 30.0 per cent w/w of available chlorine,

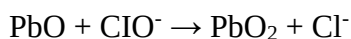
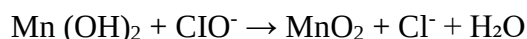
Preparation: Chlorinated lime is a compound which is obtained by the action of chlorine on calcium hydroxide. Slaked lime is spread on shelves in a suitable container. Then, the chlorine gas is introduced at the top of the chamber and then allowed to pass through the contents of the shelves. This is usually carried out at 25°C , thereby minimising the formation of calcium chloride. When absorption of chlorine gets completed, powdered lime is blown into the chamber to absorb the excess chlorine



It is known that the process has been somewhat more complex. The first products are basic chlorides, CaCl_2 , $\text{Ca}(\text{OH})_2$, H_2O and basic hypochlorite, $\text{Ca}(\text{OCl})_2$, $2\text{Ca}(\text{OH})_2$. The latter then gets changed, by the further action of chlorine on a substance which is having calcium hypochlorite. The commercial sample also having small portions of calcium chlorate.

Properties: It occurs as a dull white powder having a characteristic odour. When exposed to air, it absorbs moisture and gradually decomposes. It has been partially soluble in water and alcohol.

When bleaching powder is put in water, hypochlorite goes into the solution, and the bleaching and oxidising properties have been shown. Hypochlorites are able to oxidise many salts such as manganous salt to permanganates, Chromous salts to chromates and lead salt to lead oxide in an alkaline media.



Uses: It is also used as an ingredient in bleaching powder, used for bleaching cotton and linen. It is also used in sugar industry for bleaching sugar cane juice before crystallization. It is used as a sanitizer in outdoor swimming pools in combination with cyanuric acid stabilizer which reduces the loss of chlorine due to ultraviolet radiation. It has the bactericidal action.

Storage: It is preserved in a well closed container and kept in a cool place. It is affected by moisture and heat.

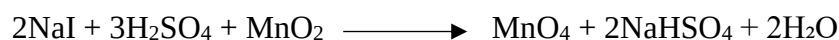
IODINE AND ITS PREPARATIONS**Chemical Formulae:** I₂**Molecular weight:** 253.8

It is having not less than 99.5 per cent of I₂.

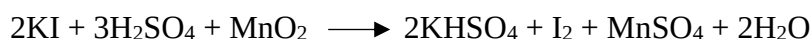
Iodine compounds are very common in nature. Sea water is also having traces of combined iodine, which gets absorbed by some specific plants and sea weeds, like Laminaria digitate, Fucus vesiculosus. Iodine also occurs in the form of sodium iodate in crude Chile saltpetre (NaNO₃).

Method of Preparation:

Iodine is manufactured by extracting kelp (sea weed's ash) with water. The solution is concentrated when the sulphate and chloride of sodium and potassium get crystallized out, leaving freely soluble sodium and potassium iodides in the mother liquor. Sulphuric acid is added to the mother liquor which then gets decanted off.

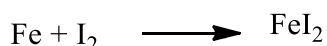
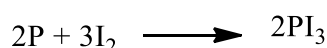


In the laboratory, it reacts by heating potassium iodide or sodium iodide with dilute sulphuric acid and manganese dioxide.



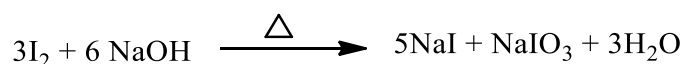
Properties: Iodine is a heavy, bluish-black, rhombic prism or plates having a metallic lustre. It is having a peculiar odour and volatilises at ordinary temperatures. At temperatures it melts. At higher temperatures, the density of iodine decreases as it dissociates $\text{I}_2 \rightarrow 2\text{I}$. It is insoluble in water but soluble in alcohol. It is freely soluble in chloroform and solvent ether and in aqueous solutions of iodides.

(i) It reacts directly with some non-metals and with many metals.

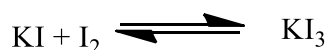


(ii) Reducing agents react with aqueous solutions of iodine and are oxidised.

(iii) With an alkali iodine reacts to form an iodide and iodate, especially with the aid of heat.



(iv) Potassium iodide is able to dissolve large quantities of iodine due to the formation of the I_3^- ion.



Assay: Iodine may be assayed by involving the oxidation-reduction titration method. About 0.5 g of iodine is first of all dissolved in a solution of 1 g of potassium iodide in 5 ml of water in an iodine flask. Then, it is diluted with 50 ml of water and acidified with 1 ml of acetic acid.

Now it is titrated with standard (N/10) sodium thiosulphate, using starch solution as an indicator.



Each ml of N/10 sodium thiosulphate = 0.01269 g of Iodine.

Uses: Iodine finds use in medicine mainly as a counter irritant and disinfectant. It is used as local germicide. Elemental iodine can exert its action when used externally. For proper thyroid functioning iodine is supplied to the body either in the elemental form or in the form of sodium or potassium iodide.

Elementary iodine is highly toxic and the starch and sodium thiosulphate are useful antidotes.

Storage: It is preserved in glass stoppered, amber coloured bottles or earthenware containers and kept in a cool place.

A. Aqueous Iodine Solution

Synonym: Lugol's solution.

It is having 5.0 per cent w/v of Iodine (4.9 to 5.1 per cent) and 10 per cent w/v of potassium iodide (9.8 to 10.2 per cent) in purified water.

Composition:

Iodine - 50 g

Potassium iodide - 100 g

Purified water sufficient to produce - 1000 ml

Preparation: Potassium iodide and iodine are first of all dissolved in 100 ml of water with trituration or shaking. Then the volume is made up to 1000 ml by adding sufficient volume of purified water.

Properties: It is a transparent, brown liquid, having the smell of iodine.

Identification: (1) With starch, aqueous iodine solution gives a blue colour. (2) The residue left after evaporation of the solution and after ignition, yields reactions which are characteristic of potassium and iodine.

Uses: It acts as a good source of iodine, and is taken internally. It possesses germicide and fungicide properties and does not bring about irritation on cuts or wounds like the tincture of iodine.

Storage: It is preserved in well-closed containers of glass or plastic which are resistant to iodine. It is not stored in metal containers because iodine attacks metal.

B. Weak Iodine Solution

Synonym: Iodine Tincture or Tincture of iodine

Iodine tincture is having 2 per cent w/v of iodine (limit 1.9-2.1 per cent) and 2.5 per cent w/v of potassium iodide (limit 2.4 - 2.6 per cent).

Composition:

Iodine – 20g

Potassium iodide – 25g

Alcohol (50 per cent) sufficient to produce – 1000ml

Preparation: Potassium iodide and iodine are first of all dissolved in sufficient alcohol (50 per cent). Then, the volume is made up to 1000 ml by adding more 50 per cent alcohol. Alcohol content is 45-48 per cent w/v.

Properties and identification: These have been the same as those described under aqueous iodine

Assay: For iodine. 10 ml of the solution is first of all diluted with 20 ml of water. Then, it is titrated with 0.1 N sodium thiosulphate using starch solution as an indicator.

Each ml of 0.1 N $\text{Na}_2\text{S}_2\text{O}_3$ = 0.01269 g of Iodine.

Uses: Its uses are same as those of aqueous iodine solution. It is a well-known and popular antiseptic, which is applied on cuts and wounds.

C. Strong Iodine Solution

It is having 10 per cent w/v of iodine (I_2) (limit 9.5-10 per cent) and 6 per cent w/v of potassium iodide. (limit 5.7-6.3 per cent).

Composition:

Iodine- 100 g

Potassium iodide - 60 g

Purified water - 100 ml

Alcohol, 90 per cent sufficient to produce - 1000 ml

Preparation: Potassium iodide and iodine are first of all dissolved in purified water. Then, the sufficient alcohol is added to produce 1000 ml.

Properties and identification: These are the same as described under aqueous iodine solution.

Uses: It finds use as an antiseptic. It is used in making all the above solutions provided potassium iodide is replaced by sodium iodide.

Storage: It is stored under conditions which have been described under aqueous iodine solution.

D. Povidone-Iodine Solution

Povidone-iodine solution is an aqueous solution of povidone-iodine. It is a complex produced by the interaction between iodine and povidone (polyvinyl pyrrolidone). The complex is having about 10 per cent w/v of available iodine.

Description: The complex occurs as a yellowish brown, amorphous powder and is having characteristic colour. It is soluble in water and alcohol. The solution is transparent in nature and has reddish-brown colour and faint smell of iodine. The aqueous solution is having acidic pH.

Action and uses: In 10 per cent povidone-iodine, the free iodine content is only 0.001 per cent this is diluted to 0.1 per cent the free iodine content gets increased and becomes more por bactericidal. Thus, povidone-iodine has to be diluted before use.

Disinfection of skin, mouth or wounds by using povidone-iodine solution has been very common. It has been found to be also effective in the management of burns and cuts. Povidone-iodine is available in wide variety of preparations for applications to the skin and mucous membrane and for disinfectant.

Important advantages of this preparation over usual iodine preparations are its water solubility, non-irritation, less toxicity and non-staining nature. It could be easily removed from skin and d by washing.

Storage: It is kept in a closed container and remains stable.

Aqueous solutions (0.1-1 per cent of available iodine), aerosol (0.5 per cent), surgical scrub (0.75-1 per cent) are commonly employed for preparations of povidone-iodine.

RADIOPHARMACEUTICALS

Radiopharmaceuticals are a unique class of pharmaceutical preparations that contain **radioactive isotopes (radioisotopes)** incorporated into a biologically active compound. These preparations are administered to patients for the **diagnosis, treatment, and monitoring** of various diseases. Unlike conventional medicines, which exert their effects through chemical or pharmacological actions, radiopharmaceuticals produce their effects by emitting **ionizing radiation**, which can either be detected externally for diagnostic imaging or used internally to destroy diseased tissues for therapeutic purposes.

Radiopharmaceuticals are the foundation of **nuclear medicine**, a specialized branch of medical science that utilizes radioactive substances for the evaluation and treatment of diseases. They provide valuable information about the **structure, function, and metabolism of organs and tissues**, allowing physicians to detect diseases at an early stage, often before anatomical changes become apparent through conventional imaging techniques such as X-rays, CT scans, or MRI.

A radiopharmaceutical consists of **two essential components**:

1. **Radioisotope (Radionuclide):** The radioactive component that emits radiation (gamma rays, beta particles, alpha particles, or positrons). The emitted radiation is either detected by imaging devices for diagnosis or used to destroy abnormal cells in therapy.
2. **Pharmaceutical Carrier:** A biologically active molecule that transports the radioisotope selectively to a specific organ, tissue, or pathological site. The carrier determines the distribution of the radiopharmaceutical within the body, ensuring that the radioactive material accumulates in the target organ.

After administration through routes such as intravenous injection, oral administration, inhalation, or direct instillation, the radiopharmaceutical circulates in the bloodstream and localizes in the target tissue due to the biological properties of the carrier. Once localized, the radionuclide emits radiation. In diagnostic applications, gamma rays or positrons emitted by the radionuclide are detected by specialized instruments such as gamma cameras, Single Photon Emission Computed Tomography (SPECT), or Positron Emission Tomography (PET) scanners, producing detailed images of the organ. In therapeutic applications, beta or alpha particles emitted by the radionuclide deliver localized radiation to destroy diseased or cancerous cells while minimizing damage to surrounding healthy tissues.

The development of radiopharmaceuticals has revolutionized modern medicine because they provide functional imaging, which assesses how an organ works rather than simply showing its structure. This enables early diagnosis of diseases such as cancer, thyroid disorders, cardiovascular diseases, neurological disorders, kidney diseases, and bone abnormalities. In addition, therapeutic radiopharmaceuticals have become important tools in the treatment of hyperthyroidism, thyroid cancer, bone metastases, neuroendocrine tumors, and certain blood disorders.

An ideal radiopharmaceutical should possess several desirable properties:

It should be non-toxic, sterile, chemically stable, highly specific for the target organ, rapidly eliminated from non-target tissues, and have an appropriate physical and biological half-life. It should emit radiation of suitable energy to produce high-quality images or effective therapeutic action while minimizing radiation exposure to the patient.

Radioactivity: The phenomenon of spontaneous emission of certain kind of invisible radiation by certain substance is called Radioactivity. The substances which emit such radiation is called Radioactive substance. It was discovered accidentally by the French Scientist Henry Becquerel.

Radiopharmaceuticals are used in medicines. It is used to treat cancerous tumors, to diagnose thyroid disorders and other metabolic disorders including brain function.

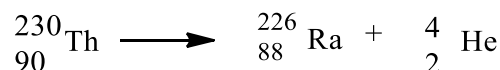
RADIOACTIVE RAYS

Radioactive radiations are composed of three important rays α , β and γ which differ very much in their nature and properties.

 α -rays

These rays or particles are positively charged. It consists of two-unit positive charge and has a mass which is nearly four times that of hydrogen atom. These are heavy, slow moving and their penetration power is slow. These rays ionise the gas through which they pass.

During the emission of α -particle from a radioactive element, atomic number decreases 2 unit and mass number decrease by 4 units.



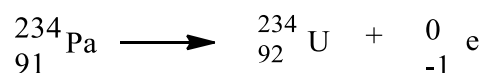
The penetrating power of alpha rays is least as compared to other emissions. Because of low penetrating power of alpha particles, elements which emits these do not find any use in biological applications as they cannot penetrate.

 β -rays

These rays or particles are negatively charged. They have negligible mass. These are having smaller mass, higher speed and thus β -particles are much more penetrating than α particle. They have lower ionising power than x-rays.

During the emission of β -particle from a radioactive element, atomic number increases by 1 unit and there is no change in mass number.

For example:



γ-rays:

These rays are neutral i.e. do not carrying charge. The particle of these rays has negligible mass. As they do not have any mass, their ionising power is also very poor. They are not affected by magnetic field and are having the speed of light. It is having more penetrating power then alpha and beta rays.

Difference Between Alpha (α), Beta (β), and Gamma (γ) Rays

Alpha (α) Rays	Beta (β) Rays	Gamma (γ) Rays
Alpha rays are streams of positively charged helium nuclei emitted from the nucleus of heavy radioactive elements.	Beta rays are streams of high-speed electrons or positrons emitted from the nucleus during radioactive decay.	Gamma rays are high-energy electromagnetic waves emitted from the nucleus after alpha or beta decay.
They consist of two protons and two neutrons and are represented as ${}^4_2\text{He}^{2+}$.	They consist of either an electron (β^-) or a positron (β^+).	They consist of photons and have no mass or charge.
They carry a +2 positive charge.	They carry a -1 charge (electron) or a +1 charge (positron).	They are electrically neutral.
They have the highest mass among the three types of radiation (4 amu).	They have a very small mass, about 1/1836 of a proton.	They have no mass.
They travel at about 5–10% of the speed of light.	They travel at about 90–99% of the speed of light.	They travel at the speed of light (3×10^8 m/s).
They possess the highest ionizing power.	They possess moderate ionizing power.	They possess the lowest ionizing power.
They have the lowest penetrating power and can travel only a few centimeters in air.	They have moderate penetrating power and can travel a few meters in air.	They have the highest penetrating power and can travel several hundred meters in air.
They cannot penetrate the outer layer of human skin but are very dangerous if inhaled or ingested.	They can penetrate the skin to a depth of a few millimetres and may damage tissues.	They can penetrate deep into the body and affect internal organs.
They can be stopped easily by a sheet of paper, clothing, or the outer layer of skin.	They require a thin sheet of aluminium or plastic for shielding.	They require thick lead blocks or concrete for effective shielding.
They are slightly deflected by electric and magnetic fields because of their large mass.	They are strongly deflected by electric and magnetic fields because of their small mass.	They are not deflected by electric or magnetic fields because they have no charge.
They are mainly used in targeted alpha therapy for the treatment of certain cancers.	They are used in the treatment of thyroid disorders, leukemia, and	They are mainly used for diagnostic imaging and external beam radiotherapy.

	other diseases, and in some diagnostic applications.	
Examples include Radium-223, Polonium-210, and Americium-241.	Examples include Iodine-131, Phosphorus-32, and Strontium-90.	Examples include Technetium-99m, Cobalt-60, and Cesium-137.

Isotopes

Atoms of an element which have the same atomic number but have different mass number are called Isotopes. In other words, isotopes are atoms of the same element whose nuclei contain the same number of protons but different number of neutrons.

When the radioactive isotopes undergo nuclear reactions and they produce α , β and γ particles. The original nuclide is called the **parent** and the product is termed as **daughter nuclide**. This phenomenon of nuclear changes is termed as disintegration or **radioactive decay**.

According to the law of radioactive decay, the quantity of a radioelement which disappears in unit time (rate of disintegration) is directly proportional to the amount present. It is independent of temperature so its energy of activation is zero.

$$\lambda = \frac{2.303}{t} \log \frac{N_0}{N}$$

N_t = No. of atoms that nucleid present after time t.

N_0 = Initial no. of atoms of the nucleid at time 0.

λ = Decay constant

Units of Radioactivity

1. Curie: The unit of radioactivity is “curie” which is symbolised as ‘c’. It may be defined as quantity of any radioactive substance which undergoes the same number of disintegrations in unit time as of 1 g of radium and is equal 3.7×10^{10} dps to disintegrations per second. Its symbol is Ci or C.

The millicurie and micro curie are equal to 10^{-3} or 10^{-6} respectively.

$$1 \text{ Millicurie} = 3.7 \times 10^7 \text{ dps}$$

$$1 \text{ Microcurie} = 3.7 \times 10^4 \text{ dps}$$

But now a days, the unit curie is replaced by Rutherford (Rd).

2. Rutherford (Rd) is defined as the amount of a radioactive substance which undergoes 106 dps.

3. Roentagen (R): It is the unit of exposure, $1R = 2.58 \times 10^{-4} \text{ CKg}^{-1}$ (C = A Coluomb)

4. RAD: It is the unit of absorbed dose, $1 \text{ rad} = 10^{-2} \text{ J Kg}^{-1}$

5. Becquerel (Bq): It is defined as one disintegration per second.

$1 \text{ Bq} = 1 \text{ disintegration per second}$

$$10^6 \text{ Bq} = 1 \text{ rd}$$

$$3.7 \times 10^{10} \text{ Bq} = 1 \text{ C}$$

Half-Life

The half-life period is defined as the time required for a radioactive isotope to decay to one half of its initial value. It is denoted by $t_{1/2}$

$$t_{1/2} = 0.693 / \lambda$$

Where λ is disintegration constant. Each radioactive isotope has its own characteristic of half-life. Shorter the half-life period of an element, greater is the number of disintegrating atoms and hence greater is its radioactivity. The half-life periods or half-lives of different radioelements vary widely ranging from fraction of seconds to millions of years.

Half-lives of various radionuclides vary considerably

E.g. Polonium- 122 has half-life of 3×10^{-7} seconds, uranium 238 has 4.5×10^4 year.

Measurement of Radioactivity

To measure the radiations of alpha, beta and gamma rays many techniques involving detection and counting of individual particles or photons have been available. It includes Ionisation Chamber, Proportional counter, Geiger-Muller counter.

1. Ionisation chamber: An ionisation chamber consists of chamber filled with gas and fitted with two electrodes kept at different electrical potentials and a measuring device to indicate the flow of electric current. The fill gas can be Ar, He, air etc. These are available in various size and shapes. They have poor resolution due to large number of charge carriers. They are operated in current mode.

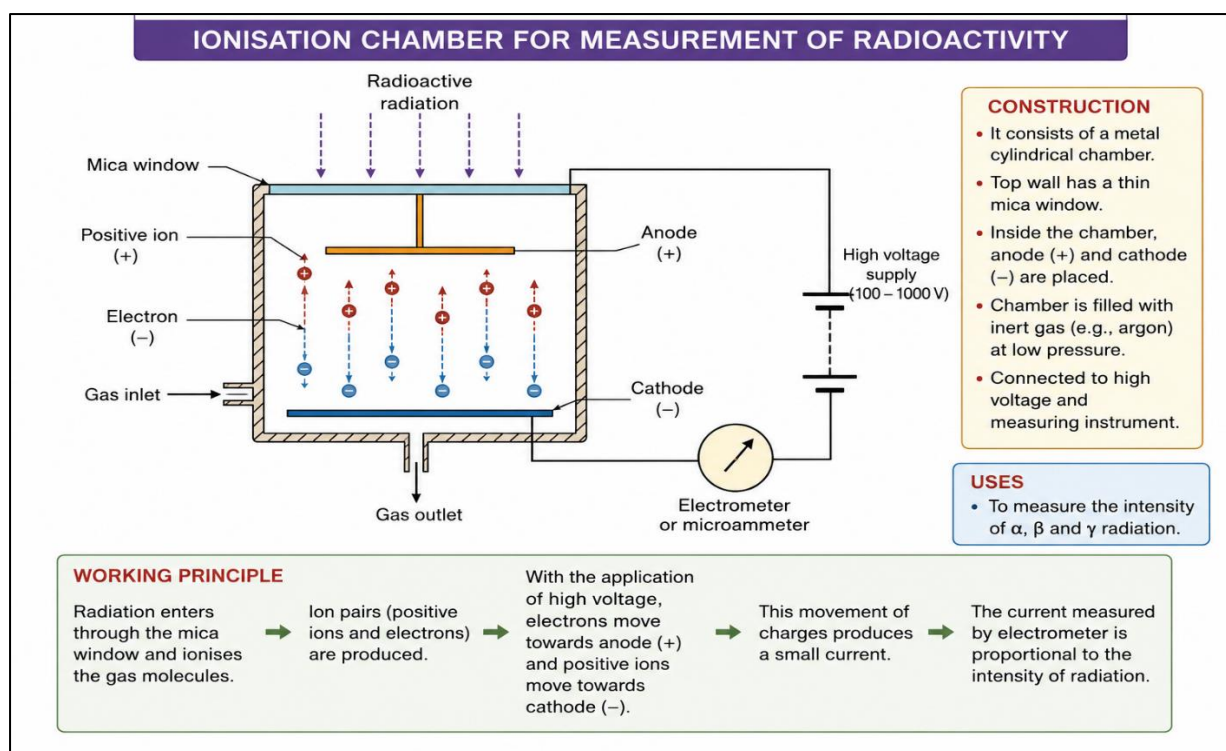


Fig: Ionisation chamber

2. Proportional counter: If the electric field gradient between the anode & cathode is increased by increasing the applied voltage, the electrons produced in the primary ionisation further ionise the gas molecule e.g. the number of ion pair is multiplied. For each primary electron liberated, a large number of additional electrons are liberated the current pulse through electrical current is greatly amplified. In a certain original number of ion pairs. Proportional counters operate in this voltage region. They are usually operated in pulse mode and are used in the form of gas filled or gas flow counters for α , β and fission frequent counting. The most common fill gas is "P-10" consisting of 90% Ar and 10% methane. The energy resolution of the proportional counter is in the range of 5-10%.

3. Geiger-Muller Counter: It is one of the oldest radiation detector types in existence, having been introduced by Geiger and Muller in 1928. It is referred to as G-M counter or simply tube. The simplicity, low cost and ease of operation of these detectors have led to their continued use to the present time. They can detect alpha, beta and gamma radiations.

It consists of a cylinder made up of stainless steel or glass coated with silver on the inner side which acts as cathode. Coaxially inside the tube a mounted fine wire works as an anode. It is having the mixture of ionizing gas which contains a small proportion quenching vapour are:

i) to prevent the false pulse,

ii) to absorb the photons emitted by excited atoms and molecules returning to their ground state. Chlorine, bromine, ethyl alcohol and ethyl formate are commonly used quenching agents. Radiation when enters the tube through a thin section of outer wall causes ionisation of atoms of the gas. When a high voltage is maintained between two electrodes, the electrons and

charged ions are attracted by the anode and cathode respectively. Each particle of radiation produces a brief flow or pulse of current which can be recorded by a scalar.

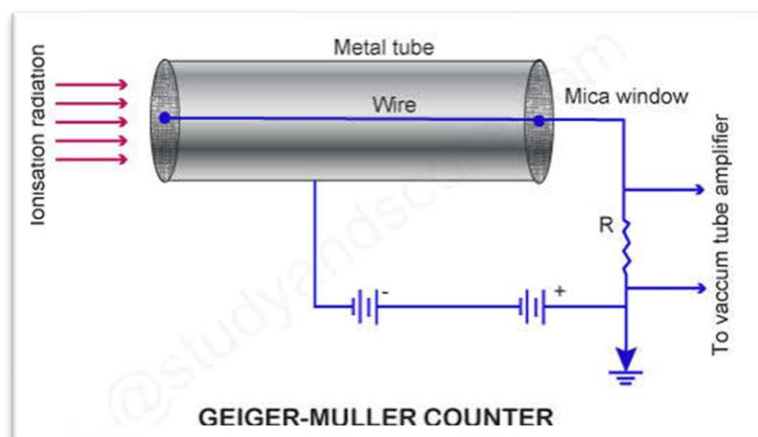


Fig: Geiger Muller counter

Applications of Radioisotopes

Radioisotopes are unstable isotopes of elements that emit ionizing radiation such as alpha (α), beta (β), or gamma (γ) rays during radioactive decay. Owing to their ability to emit detectable radiation and their unique physical and chemical properties, radioisotopes are extensively used in medicine, pharmacy, industry, agriculture, scientific research, environmental studies, and archaeology. They have become indispensable tools for disease diagnosis, cancer treatment, quality control, sterilization, and research.

The major applications of radioisotopes are described below.

1. Radioisotopes in Diagnosis

Radioisotopes have revolutionized modern medicine by enabling the early diagnosis and effective treatment of numerous diseases. In nuclear medicine, small quantities of radiopharmaceuticals containing radioisotopes are administered to patients. These radiopharmaceuticals accumulate selectively in specific organs or tissues, where the emitted radiation is detected by specialized instruments such as gamma cameras, Single Photon Emission Computed Tomography (SPECT), or Positron Emission Tomography (PET) scanners. This allows physicians to obtain detailed information about the structure and function of organs, often before anatomical changes become visible through conventional imaging techniques.

For example, 1. Technetium-99m (Tc-99m) is the most widely used diagnostic radioisotope because of its short half-life of six hours and its emission of gamma radiation, which produces high-quality images with minimal radiation exposure to the patient. It is extensively used for imaging the bones, kidneys, liver, heart, lungs, and brain.

2. Fluorine-18, commonly administered as Fluorodeoxyglucose (^{18}F -FDG), is used in PET scans for detecting cancers, evaluating brain metabolism, and assessing cardiac function.

3. Iodine-123 is specifically used for thyroid imaging and thyroid function studies because it is selectively taken up by thyroid tissue.

2. Radioisotopes in therapeutics

Radioisotopes are widely employed for therapeutic purposes.

For example: Iodine-131 is used for the treatment of hyperthyroidism and thyroid cancer because it accumulates in the thyroid gland and emits beta particles that destroy abnormal thyroid tissue.

Phosphorus-32 is used in the treatment of blood disorders such as polycythemia vera and certain types of leukemia.

Radium-223 is used to relieve pain and treat bone metastases associated with advanced prostate cancer, while **Lutetium-177** has become an important therapeutic radioisotope for treating neuroendocrine tumors and metastatic prostate cancer.

3. Sterilization of Medical Products

Gamma-emitting radioisotopes such as **Cobalt-60** are extensively used for sterilizing medical equipment and pharmaceutical products. Unlike heat sterilization, gamma irradiation can sterilize heat-sensitive materials without causing physical damage. Surgical gloves, disposable syringes, catheters, sutures, dressings, implants, and pharmaceutical packaging materials are routinely sterilized using this method. Gamma radiation effectively destroys bacteria, viruses, fungi, and bacterial spores, ensuring complete sterility and patient safety.

4. Scientific Research

Radioisotopes have become indispensable research tools in biology, chemistry, biochemistry, and molecular medicine. They are used as tracers to investigate biochemical reactions, enzyme activities, metabolic pathways, DNA replication, RNA synthesis, protein synthesis, hormone production, and cell division.

Carbon-14, Tritium, Phosphorus-32, and Sulphur-35 are among the most commonly used radioisotopes in laboratory research. Because radioactive tracers behave chemically like their stable counterparts, they enable scientists to follow the movement of atoms through complex biological systems with remarkable accuracy.

5. Industrial Applications

Radioisotopes have numerous applications in various industries because they allow non-destructive testing and precise process control. In industrial radiography, gamma-emitting radioisotopes such as Cobalt-60 and Iridium-192 are used to inspect welds, pipelines, pressure vessels, and aircraft components without causing any damage. The radiation passes through the material and produces an image that reveals internal defects such as cracks, voids, or corrosion.

1. Sodium Iodide I-131 (Na^{131}I)

Sodium Iodide I-131 (Na^{131}I) is one of the most important therapeutic radiopharmaceuticals used in nuclear medicine. It contains the radioactive isotope Iodine-131 (^{131}I) in the form of sodium iodide. Iodine-131 is a radioactive isotope of iodine that emits both beta (β) particles and gamma (γ) rays, making it useful for both therapeutic and diagnostic purposes.

Preparation:

Sodium Iodide I-131 is prepared using radioactive Iodine-131 produced in a nuclear reactor. The radionuclide is generally formed by **neutron irradiation of Tellurium-130**, which is converted into Tellurium-131. Tellurium-131 subsequently undergoes beta decay to produce radioactive Iodine-131. After production, Iodine-131 is chemically separated, purified, and converted into sodium iodide by reacting it with sodium hydroxide or sodium carbonate under carefully controlled conditions.

Sodium Iodide 1-131 solutions are suitable for either oral or I.V. administration. The solutions are clear and colourless, but over a period of time both the solution and glass may darken due to the effects of radiation. The pH of both solutions is between 7.5 and 9.0. For injection, a suitable preservative such as benzyl alcohol is added. A reducing agent such as sodium thiosulphate is added to the solution to prevent the oxidation of sodium iodide in aqueous solutions.

Sodium Iodide I-131 solution should not contain less than 90% but not more than 110% of the labelled amount of iodine-131 as iodide which is expressed in microcuries or millicuries at the time indicated in the labelling

Applications of Sodium Iodide I-131 (Na^{131}I)

1. Treatment of Hyperthyroidism

Sodium Iodide I-131 is primarily used for the treatment of hyperthyroidism, a condition in which the thyroid gland produces excessive amounts of thyroid hormones. After oral administration, the radiopharmaceutical is selectively absorbed by the thyroid gland through the sodium-iodide symporter (NIS). The beta particles emitted by Iodine-131 destroy the overactive thyroid follicular cells, thereby reducing hormone production and restoring normal thyroid function. It is highly effective in treating Graves' disease, toxic multinodular goitre, and toxic thyroid adenoma.

2. Treatment of Differentiated Thyroid Cancer

Sodium Iodide I-131 is widely used in the treatment of papillary and follicular thyroid carcinoma. After surgical removal of the thyroid gland (thyroidectomy), small amounts of residual thyroid tissue or microscopic cancer cells may remain. Administration of I-131 selectively destroys these remaining thyroid cells through beta radiation, thereby reducing the risk of recurrence and improving long-term survival. This treatment is known as radioiodine ablation therapy.

3. Treatment of Metastatic Thyroid Cancer

In patients with thyroid cancer that has spread to distant organs such as the lungs, bones, or lymph nodes, Sodium Iodide I-131 is administered to destroy metastatic thyroid cancer cells. Since these cells retain the ability to concentrate iodine, the emitted beta radiation selectively damages the cancer cells while causing minimal injury to surrounding healthy tissues.

4. Thyroid Uptake Test

Sodium Iodide I-131 is used in thyroid uptake studies to assess the functional activity of the thyroid gland. A small diagnostic dose is administered orally, and the amount of radioiodine absorbed by the thyroid is measured using a thyroid uptake probe. The test helps evaluate thyroid function and diagnose conditions such as hyperthyroidism, hypothyroidism, and thyroiditis.

5. Thyroid Scintigraphy (Thyroid Imaging)

The gamma rays emitted by Iodine-131 allow visualization of the thyroid gland using a gamma camera. Thyroid scintigraphy helps determine the size, shape, position, and functional status of the thyroid gland. It is useful in detecting hot nodules, cold nodules, diffuse goitre, ectopic thyroid tissue, and residual thyroid tissue after surgery.

Packaging and Storage: The solution has to be prepared in single dose or multiple dose containers that have been previously treated to prevent absorption.

So as to avoid absorption of radionuclides on the walls of the containers including laboratory vessels, it has been recommended that containers used to handle sodium iodide I-131 solutions should be first of all rinsed with a solution having approximately 0.8 per cent of sodium bisulfate and 0.25 per cent of sodium iodide and then with water until the last rinsing has been neutral to litmus.

Other requirements regarding labelling and expiration date have been almost similar to those for other radioactive solution. The expiration date for Sodium Iodide Solution has been not later than one month after the date of standardization.

2. Technetium-99m

Technetium-99m (^{99m}Tc) is the most widely used diagnostic radionuclide in nuclear medicine. The letter "m" in Technetium-99m denotes its metastable (excited) nuclear state, which possesses higher energy than the ground state of Technetium-99 (^{99}Tc).

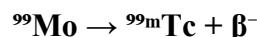
Technetium-99m is an artificially produced radioactive isotope of technetium. It emits gamma rays of 140 keV, which are ideal for imaging using a gamma camera or Single Photon Emission Computed Tomography (SPECT).

The physical half-life of Technetium-99m is approximately 6 hours, making it suitable for diagnostic imaging because it remains in the body long enough to obtain quality images but

decays rapidly afterward, reducing unnecessary radiation exposure. Because of its favourable physical properties, simple chemistry, and ability to form stable complexes with numerous pharmaceuticals, Technetium-99m has become the most versatile radionuclide for imaging various organs such as the heart, kidneys, liver, lungs, bones, thyroid, brain, and hepatobiliary system.

Preparation Procedure: The parent radionuclide Molybdenum-99 (^{99}Mo) undergoes beta decay to produce Technetium-99m.

Decay reaction:



- Half-life of Molybdenum-99 = approximately **66 hours**
- Half-life of Technetium-99m = approximately **6 hours**

Generator Method:

The generator consists of a column containing alumina (Al_2O_3) on which radioactive molybdate ions ($^{99}\text{MoO}_4^{2-}$) are adsorbed. As Molybdenum-99 decays, Technetium-99m is formed as **pertechnetate ion (TcO_4^-)**.

When sterile normal saline is passed through the column, only Technetium-99m pertechnetate is eluted, while Molybdenum-99 remains strongly adsorbed to the alumina. The collected sterile solution is called Sodium Pertechnetate Tc-99m Injection.

The generator can be eluted every 24 hours because new Technetium-99m continuously forms from the decay of Molybdenum-99.

Properties of Technetium-99m:

Physical Properties

- Radioactive isotope of technetium.
- Atomic number: **43**
- Mass number: **99**
- Exists in a metastable nuclear state.
- Physical half-life: **6.02 hours**
- Decays by **isomeric transition**.
- Emits gamma photons of **140 keV**.

Chemical Properties

- Exists mainly as the **pertechnetate ion (TcO_4^-)**.
- Chemically resembles permanganate and perrhenate ions.
- Can exist in oxidation states ranging from **-1 to +7**.
- Easily forms stable complexes with many ligands.
- Compatible with numerous pharmaceutical compounds.
- Readily reduced by stannous ions during kit preparation.

Applications of Technetium-99m (99mTc)

Technetium-99m is the most extensively used radionuclide in diagnostic nuclear medicine because it can be attached to different pharmaceutical compounds that selectively accumulate in specific organs or tissues.

1. Bone Imaging (Skeletal Scintigraphy)

Technetium-99m labelled methylene diphosphonate (Tc-99m MDP) or hydroxymethylene diphosphonate (Tc-99m HDP) is widely used for bone imaging. These compounds have a high affinity for hydroxyapatite crystals in bones and accumulate in areas where bone formation and re-modelling are increased.

2. Cardiac Imaging (Myocardial Perfusion Scintigraphy)

Technetium-99m labelled sestamibi (MIBI) are commonly used radiopharmaceuticals for myocardial perfusion imaging. These compounds are absorbed by healthy cardiac muscle cells in proportion to coronary blood flow. Areas receiving adequate blood supply show normal uptake, whereas regions with reduced blood flow demonstrate decreased uptake.

3. Renal Imaging

Technetium-99m labelled compounds such as DTPA, MAG3, and DMSA are extensively used to evaluate kidney function and morphology. Tc-99m DTPA is filtered through the glomeruli and is primarily used to assess glomerular filtration rate (GFR). Tc-99m MAG3 is secreted by the renal tubules and provides information regarding renal perfusion and tubular function. Tc-99m DMSA accumulates in the renal cortex and is used to evaluate renal cortical integrity.

Renal scintigraphy helps diagnose urinary tract obstruction, renal artery stenosis, congenital kidney abnormalities, renal scars resulting from recurrent urinary tract infections.

4. Thyroid Imaging

Technetium-99m pertechnetate behaves similarly to iodide and is actively transported into thyroid follicular cells by the sodium-iodide symporter. However, unlike radioactive iodine, it is not incorporated into thyroid hormones because it is not organified within the thyroid gland.

Technetium-99m thyroid scanning is widely used for evaluating thyroid nodules, determining whether nodules are functioning ("hot") or non-functioning ("cold"), diagnosing Graves' disease, toxic multinodular goiter, and assessing diffuse thyroid enlargement.

Storage

- Technetium-99m is stored in **lead-shielded containers** (lead pots or lead castles) to protect personnel from unnecessary radiation exposure.
- The **Mo-99/Tc-99m generator** is also housed in a heavily shielded lead container during storage and use.
- Sodium pertechnetate solution should be kept under **aseptic conditions** in sterile, pyrogen-free vials after elution.

- Storage should be at **controlled room temperature (generally 20–25°C)** unless the manufacturer's instructions specify otherwise.
- Because of the **6-hour half-life**, freshly eluted Technetium-99m should be used as soon as possible to ensure adequate radioactivity for imaging.

3. Cobalt-60

Cobalt-60 (^{60}Co) is a radioactive isotope of cobalt that is widely used in medicine, industry, agriculture, and scientific research. It is an artificially produced radionuclide, meaning it is not found naturally in significant amounts but is produced in a nuclear reactor. Cobalt-60 is one of the strongest sources of gamma radiation and has been used for many years in cancer treatment and sterilization of medical products.

Preparation of Cobalt-60

Cobalt-60 is prepared artificially in a **nuclear reactor** by exposing stable **Cobalt-59** (^{59}Co) to a stream of slow-moving neutrons.

The nuclear reaction is:



During this process, the stable Cobalt-59 nucleus absorbs a neutron and becomes radioactive Cobalt-60. After production, the radioactive cobalt is purified, sealed inside stainless-steel capsules, and supplied for medical and industrial use. These sealed capsules prevent leakage of radioactive material and provide safe handling.

Properties of Cobalt-60

- Radioactive isotope of cobalt.
- Atomic number: **27**
- Mass number: **60**
- Physical half-life: **5.27 years**
- Emits two high-energy gamma rays of about **1.17 MeV and 1.33 MeV**.
- Strong source of penetrating gamma radiation.
- Chemically behaves like ordinary cobalt.
- Forms stable compounds with oxygen, chlorine, and other elements.

Applications of Cobalt-60

1. Cancer Treatment (Radiotherapy)

The most important medical use of Cobalt-60 is in radiotherapy for the treatment of cancer. The high-energy gamma rays produced by Cobalt-60 can penetrate deep into the body and destroy cancer cells by damaging their DNA. This prevents the cancer cells from growing and dividing. Cobalt-60 teletherapy units have been widely used to treat cancers of the head and neck, breast, cervix, prostate, lungs, and brain. During treatment, the radiation beam is carefully directed only at the tumor to reduce damage to surrounding healthy tissues.

2. Sterilization of Medical Equipment

Cobalt-60 is extensively used for sterilizing medical and surgical products using gamma radiation. The radiation destroys bacteria, viruses, fungi, and other microorganisms without the need for heat or chemicals. Many heat-sensitive items such as syringes, surgical gloves, catheters, dressings, implants, and disposable medical devices are sterilized using Cobalt-60. Since the products remain sealed during sterilization, the risk of contamination after sterilization is very low. This method provides highly effective sterilization while maintaining the quality of the products.

3. Sterilization of Pharmaceutical Products

Certain pharmaceutical products and laboratory materials that cannot tolerate high temperatures are sterilized using Cobalt-60 gamma radiation. Packaging materials, culture media, laboratory supplies, and some biological products can also be sterilized in this way. Gamma sterilization increases the safety and shelf life of these products without leaving any chemical residue.

4. Radiation Therapy Research

Cobalt-60 is used in research laboratories to study the effects of radiation on living cells, tissues, microorganisms, and different materials. Researchers use it to improve radiation treatment techniques, develop safer radiation doses, and study radiation protection methods.

5. Agricultural Applications

In agriculture, Cobalt-60 is used to develop improved crop varieties by exposing seeds to controlled doses of radiation. The radiation induces useful genetic mutations that may produce plants with higher yield, better disease resistance, or improved tolerance to environmental stress.

6. Calibration of Radiation Instruments

Cobalt-60 is commonly used as a standard radiation source for testing and calibrating radiation detection instruments such as dosimeters, gamma cameras, radiation monitors, and survey meters. Calibration ensures that these instruments provide accurate radiation measurements in hospitals, industries, and research laboratories.

Storage of Cobalt-60

- Cobalt-60 sources are stored in sealed stainless-steel capsules to prevent leakage of radioactive material.
- These sealed sources are kept inside thick lead or concrete shielded containers, which absorb most of the gamma radiation and reduce exposure.

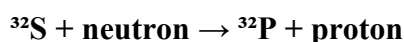
4. Phosphorus-32

Phosphorus is an essential element in the human body and is present in bones, teeth, DNA, RNA, ATP, and many body tissues. Radioactive Phosphorus-32 behaves chemically like ordinary phosphorus and becomes incorporated into cells and tissues where phosphorus is normally utilized. This property allows it to deliver radiation directly to diseased tissues.

Preparation of Phosphorus-32

Phosphorus-32 is produced artificially in a **nuclear reactor** by exposing sulfur to neutrons.

The common nuclear reaction is:



Another method is by irradiating phosphorus compounds with neutrons in a nuclear reactor.

Properties of Phosphorus-32

- Radioactive isotope of phosphorus.
- Atomic number: **15**
- Mass number: **32**
- Physical half-life: **14.3 days**
- Decays by **beta decay**.
- Changes into stable **Sulfur-32**.
- Chemically identical to ordinary phosphorus.
- Becomes incorporated into bones, DNA, RNA, and other phosphorus-containing compounds.

Applications of Phosphorus-32

1. Treatment of Blood Disorders

One of the most important medical uses of Phosphorus-32 is the treatment of certain blood disorders, especially **polycythemia vera**, a condition in which the bone marrow produces too many red blood cells. After administration, Phosphorus-32 accumulates in the bone marrow and emits beta radiation that reduces excessive blood cell production. This helps normalize blood counts, decreases blood viscosity, and lowers the risk of complications such as blood clots and stroke.

2. Treatment of Certain Cancers

Phosphorus-32 has been used for treating some cancers because its beta radiation destroys rapidly dividing cells. It has been employed in selected cases of chronic leukemia and certain bone-related cancers. The emitted beta particles damage the DNA of cancer cells, stopping their growth and causing cell death while limiting radiation to surrounding healthy tissues due to their short penetration range.

3. Bone and Joint Disorders

Phosphorus-32 has been used in the treatment of certain painful bone diseases and chronic inflammatory joint conditions. When administered locally, the beta radiation helps reduce inflammation and excessive tissue growth. It has also been used experimentally for relieving pain associated with some bone disorders by reducing abnormal cell activity.

4. Biological and Medical Research

Phosphorus-32 is used to investigate DNA replication, RNA synthesis, protein production, enzyme activity, cell division, and energy transfer within living cells. It has played a major role in advancing molecular biology, genetics, and biochemistry by helping scientists understand fundamental biological processes.

5. Environmental Studies

Phosphorus-32 is used in environmental research to trace the movement of phosphorus in rivers, lakes, groundwater, and soil. It helps scientists understand nutrient cycling, water pollution, and the transport of phosphorus through ecosystems. These studies are important for protecting water quality and managing environmental resources.

Storage of Phosphorus-32

- Phosphorus-32 should be stored in well-labelled, leak-proof containers to prevent contamination.
- Since beta particles are effectively absorbed by plastic, the radioactive solution is generally stored in plastic or acrylic shielded containers rather than lead. Thick lead shielding is usually unnecessary because it can produce secondary X-rays.

Storage, Handling, and Disposal of Radiopharmaceuticals

A. Storage of Radiopharmaceuticals

1. Radiopharmaceuticals should be stored only in designated radioactive storage areas that are approved by the radiation safety authority.
2. They should be kept in lead-shielded containers (lead pots or lead castles) to reduce radiation exposure to personnel.
3. Storage areas should be clearly labelled with radiation warning signs and access should be restricted to authorized personnel only.
4. Radiopharmaceuticals should be stored according to the manufacturer's recommended temperature and storage conditions to maintain their stability and sterility.
5. Different radionuclides should be properly identified and labelled with the radionuclide name, activity, date, time of preparation, and expiry time.
6. The storage area should be clean, dry, well-ventilated, and free from contamination to ensure product quality and safety.
7. Regular radiation monitoring and contamination surveys should be carried out, and inventory records should be maintained for all radioactive materials.

B. Handling of Radiopharmaceuticals

1. Radiopharmaceuticals should be handled only by trained and authorized personnel following radiation safety guidelines.
2. The ALARA principle (As Low As Reasonably Achievable) should always be followed by minimizing handling time, maximizing distance, and using appropriate shielding.
3. Personnel should wear personal protective equipment (PPE) such as laboratory coats, gloves, face masks, and personal dosimeters while handling radioactive materials.
4. Suitable shielding devices such as lead syringe shields, lead glass screens, tongs, and forceps should be used to reduce radiation exposure.
5. Aseptic techniques should be maintained throughout preparation and administration to prevent microbial contamination of radiopharmaceuticals.
6. Eating, drinking, smoking, or applying cosmetics should be strictly prohibited in areas where radiopharmaceuticals are handled.
7. Hands and work surfaces should be checked regularly with radiation monitoring instruments, and any radioactive spills should be cleaned immediately using approved decontamination procedures.

C. Disposal of Radiopharmaceuticals

1. Radioactive waste should be segregated according to its physical form (solid, liquid, or gaseous) and radioactive half-life before disposal.
2. Short-lived radioactive waste should be stored in designated decay storage areas until the radioactivity decreases to safe levels before disposal.
3. Liquid radioactive waste should be disposed of only according to national regulatory guidelines and should never be discharged without authorization.
4. Solid radioactive waste such as contaminated syringes, gloves, vials, absorbent paper, and tubing should be collected in properly labelled radioactive waste containers.
5. Sharps contaminated with radioactive materials should be disposed of in radiation-labelled puncture-resistant sharps containers.
6. Records of radioactive waste generation, storage, transfer, and disposal should be maintained for regulatory inspection and safety purposes.

Adhering to Regulatory Guidelines for Safety

Adhering to regulatory guidelines means that all activities related to the storage, handling, transport, use, and disposal of radiopharmaceuticals must be carried out according to the rules and regulations established by national and international radiation safety authorities. These guidelines are designed to protect patients, healthcare workers, the public, and the environment from unnecessary radiation exposure.

1. ALARA (As Low As Reasonably Achievable)

Definition:

ALARA stands for As Low As Reasonably Achievable. It is the basic principle of radiation protection, which states that radiation exposure should be kept as low as possible while still achieving the required medical or research purpose.

Three Principles of ALARA:

- **Time:** Minimize the time spent near radioactive sources to reduce radiation exposure.
- **Distance:** Maintain the maximum possible distance from the radioactive source because radiation intensity decreases with increasing distance.
- **Shielding:** Use suitable shielding materials such as lead, tungsten, acrylic, or concrete to absorb radiation and protect workers.

Importance:

- Reduces radiation dose to healthcare workers and patients.
- Minimizes the risk of radiation-induced health effects.
- Ensures safe handling of radiopharmaceuticals.
- Promotes good radiation safety practices in hospitals and laboratories.

2. Atomic Energy Regulatory Board (AERB)

Definition:

The Atomic Energy Regulatory Board (AERB) is the national regulatory authority in India responsible for ensuring the safe use of radioactive materials and nuclear energy. It was established by the Government of India in 1983 under the Atomic Energy Act, 1962.

Functions of AERB:

- Regulates the use of radioactive materials in medicine, industry, agriculture, and research.
- Issues licenses for the installation and operation of radiation facilities.
- Develops radiation safety standards and guidelines.
- Conducts inspections and safety audits of radiation facilities.
- Monitors radiation exposure to workers and the public.
- Ensures the safe transport, storage, and disposal of radioactive waste.
- Promotes radiation safety training and awareness programs.

Importance:

AERB protects patients, radiation workers, the public, and the environment by ensuring that radioactive materials are used safely and in accordance with national regulations.

3. Atomic Energy Act, 1962

Definition: The Atomic Energy Act, 1962 is an Act passed by the Parliament of India to regulate the development, control, and peaceful use of atomic energy and radioactive substances in the country.

Objectives of the Act:

- Regulate the production, possession, transport, and use of radioactive materials.
- Ensure the safe use of radiation in medicine, industry, agriculture, and research.
- Protect workers, patients, and the public from radiation hazards.
- Regulate the disposal of radioactive waste.
- Establish rules for licensing and inspection of radiation facilities.
- Prevent the misuse of radioactive materials.
- Promote the peaceful applications of atomic energy.

Importance:

The Act provides the legal framework for radiation safety in India and forms the basis for the functioning of the Atomic Energy Regulatory Board (AERB).

4. International Atomic Energy Agency (IAEA)

Definition: The International Atomic Energy Agency (IAEA) is an international organization established in 1957. Its headquarters are located in Vienna, Austria. The IAEA works under the United Nations (UN) system to promote the safe, secure, and peaceful use of nuclear energy worldwide.

Functions of IAEA:

- Develops international radiation safety standards and guidelines.
- Promotes the peaceful use of nuclear science and technology.
- Provides technical support and training to member countries.
- Monitors the safe use of radioactive materials and nuclear facilities.
- Supports research and development in nuclear medicine and radiopharmaceuticals.
- Helps in the safe management and disposal of radioactive waste.
- Encourages international cooperation in the field of nuclear science and medicine.

Points to remember

- **Acidifiers** increase gastric acidity and are used in conditions of hypochlorhydria.
 - **Antacids** neutralize excess gastric acid and provide rapid relief from hyperacidity and peptic ulcers.
 - An ideal antacid should act quickly, have a prolonged effect, and should not cause systemic alkalosis or constipation.
 - Combination antacids are preferred because they improve efficacy and minimize adverse effects such as constipation or diarrhea.
 - **Magnesium hydroxide** acts as both an antacid and a mild laxative, while aluminium hydroxide gel may cause constipation.
 - Sodium bicarbonate is a systemic antacid with rapid onset but prolonged use may cause **alkalosis** and acid rebound.
 - Cathartics promote bowel movements by increasing intestinal water content or stimulating intestinal motility.
 - Hydrogen peroxide, potassium permanganate, iodine, boric acid, and chlorinated lime are commonly used antimicrobial agents with different mechanisms of action.
 - **Oxidizing agents** such as hydrogen peroxide and potassium permanganate destroy microorganisms by releasing oxygen or causing oxidation.
 - Proper concentration and method of application are essential to ensure effectiveness and avoid tissue irritation.
-
- **Radiopharmaceuticals**
 - **Radioactivity** is the spontaneous emission of radiation from unstable atomic nuclei.
 - Radiopharmaceuticals are used for both diagnosis and treatment of various diseases.
 - Technetium-99m is the most commonly used diagnostic radioisotope because of its short half-life and suitable gamma emission.
 - Sodium Iodide I-131 is mainly used for the diagnosis and treatment of thyroid disorders.
 - Cobalt-60 is widely used in radiotherapy for the treatment of cancer.
 - Phosphorus-32 is used in the treatment of certain blood disorders and some cancers.
 - Follow the **ALARA (As Low As Reasonably Achievable)** principle to minimize radiation exposure.
 - Always use appropriate shielding, maintain distance, and reduce exposure time while handling radioactive materials.
 - Radiopharmaceuticals should be stored in properly shielded and clearly labelled containers.
 - Radioactive waste must be disposed of according to **AERB, IAEA**, and other applicable regulatory guidelines to ensure safety.

Case-Based Learning (CBL)

Case: Hyperacidity due to Improper Diet

A 45-year-old man visits the pharmacy with complaints of burning pain in the upper abdomen, sour belching, and heartburn for the past two weeks. He consumes spicy food regularly and drinks 4–5 cups of tea daily. The pharmacist recommends an antacid containing Aluminium hydroxide gel and Magnesium hydroxide.

Questions

1. What is the most probable condition affecting the patient?
2. Why is a combination of Aluminium hydroxide and Magnesium hydroxide preferred over a single antacid?
3. Explain the mechanism of action of antacids in relieving the patient's symptoms.
4. What lifestyle modifications should be advised to prevent recurrence?

Case: Diagnosis of Thyroid Disease

A 38-year-old woman presents with weight loss, increased sweating, nervousness, and swelling in the neck. The physician advises a thyroid scan using Sodium Iodide I-131 to evaluate thyroid function. The nuclear medicine technician explains radiation safety precautions before the procedure.

Questions

1. Why is Sodium Iodide I-131 used in thyroid disorders?
2. What type of radiation is emitted by I-131?
3. What radiation safety precautions should be followed after the procedure?
4. Mention one diagnostic and one therapeutic application of I-131.

Problem Based Learning

A 30-year-old patient visits the pharmacy with complaints of constipation for the last four days. The patient has not responded to dietary changes and asks the pharmacist to recommend a suitable bowel movement promoter from Magnesium hydroxide, Sodium orthophosphate, Sodium potassium tartrate, or Magnesium trisilicate.

1. Identify the patient's problem.
2. Which agent would you recommend and why?
3. Explain the mechanism of action of the selected agent.
4. What counselling points should be given to ensure its safe and effective use?

Problem

A technician in the nuclear medicine department is assigned to transport and handle a vial of Technetium-99m for a diagnostic scan. The supervisor notices that the technician is not following all the recommended radiation safety precautions.

1. Identify the safety issue in this situation.
2. Which radiation safety principles should the technician follow while handling Technetium-99m?
3. What are the correct methods for the storage and disposal of radiopharmaceuticals?
4. Why is it important to follow ALARA, AERB, and IAEA guidelines during handling and disposal?

Multiple choice questions

Gastrointestinal Agents

Q1. Dilute Hydrochloric Acid is primarily used in the treatment of:

- A. Hyperchlorhydria
- B. Achlorhydria
- C. Diarrhoea
- D. Gastric ulcer

Answer: B. Achlorhydria

Q2. Which of the following acidifiers is administered orally to increase gastric acidity?

- A. Boric acid
- B. Sodium acid phosphate
- C. Potassium permanganate
- D. Sodium bicarbonate

Answer: B. Sodium acid phosphate

Q3. The main function of an acidifier is to:

- A. Neutralize gastric acid
- B. Increase gastric acidity
- C. Prevent constipation
- D. Reduce intestinal motility

Answer: B. Increase gastric acidity

Q4. An ideal antacid should possess all of the following properties EXCEPT:

- A. Rapid onset of action
- B. High acid-neutralizing capacity
- C. Produce systemic alkalosis
- D. Be non-toxic

Answer: C. Produce systemic alkalosis

Q5. Sodium bicarbonate is classified as a:

- A. Non-systemic antacid
- B. Systemic antacid
- C. Saline cathartic
- D. Acidifier

Answer: B. Systemic antacid

Q6. The reaction of sodium bicarbonate with gastric hydrochloric acid produces:

- A. Hydrogen gas
- B. Carbon dioxide
- C. Oxygen
- D. Nitrogen

Answer: B. Carbon dioxide

Q7. Excessive use of sodium bicarbonate may lead to:

- A. Metabolic alkalosis
- B. Metabolic acidosis
- C. Hyperglycaemia
- D. Hypotension

Answer: A. Metabolic alkalosis

Q8. Aluminium hydroxide gel is preferred over sodium bicarbonate because it:

- A. Produces carbon dioxide
- B. Causes acid rebound
- C. Acts as a non-systemic antacid with prolonged action
- D. Is rapidly absorbed

Answer: C. Acts as a non-systemic antacid with prolonged action

Q9. Which combination is most commonly used in antacid formulations?

- A. Sodium bicarbonate + Potassium permanganate
- B. Aluminium hydroxide + Magnesium hydroxide
- C. Boric acid + Iodine

D. Hydrogen peroxide + Chlorinated lime

Answer: B. Aluminium hydroxide + Magnesium hydroxide

Q10. The rationale for combining aluminium hydroxide with magnesium hydroxide is that:

A. Both increase gastric acid secretion.

B. Aluminium hydroxide causes diarrhoea, which is balanced by magnesium hydroxide.

C. Magnesium hydroxide causes constipation, which is balanced by aluminium hydroxide.

D. Aluminium hydroxide causes constipation, whereas magnesium hydroxide causes diarrhoea, resulting in balanced bowel function.

Answer: D. Aluminium hydroxide causes constipation, whereas magnesium hydroxide causes diarrhoea, resulting in balanced bowel function

Q11. Which of the following is the primary therapeutic use of antacids?

A. To increase gastric acid secretion

B. To neutralize excess gastric acid

C. To stimulate intestinal motility

D. To prevent bacterial infections

Answer: B. To neutralize excess gastric acid

Q12. An ideal antacid should possess which one of the following properties?

A. Produce systemic alkalosis

B. Cause acid rebound

C. Rapid onset with prolonged duration of action

D. Be completely absorbed from the gastrointestinal tract

Answer: C. Rapid onset with prolonged duration of action

Q13. Which of the following is classified as a systemic antacid?

A. Magnesium trisilicate

C. Sodium bicarbonate

B. Aluminium hydroxide gel

D. Magnesium hydroxide

Answer: C. Sodium bicarbonate

Q14. Which antacid reacts with hydrochloric acid to produce carbon dioxide, leading to gastric distension?

A. Aluminium hydroxide gel

C. Sodium bicarbonate

B. Magnesium hydroxide

D. Magnesium trisilicate

Answer: C. Sodium bicarbonate

Q15. Aluminium hydroxide gel is often combined with magnesium hydroxide because:

A. Both produce constipation.

B. Both produce diarrhoea.

C. Magnesium hydroxide counteracts the constipating effect of aluminium hydroxide.

D. Aluminium hydroxide increases gastric acidity.

Answer: C. Magnesium hydroxide counteracts the constipating effect of aluminium hydroxide.

Q16. Which of the following antacids has the longest duration of action due to the formation of a protective colloidal silica gel?

- A. Sodium bicarbonate
- B. Magnesium trisilicate
- C. Calcium carbonate
- D. Sodium acid phosphate

Answer: B. Magnesium trisilicate

Q17. A patient with chronic kidney disease should avoid excessive use of magnesium-containing antacids primarily because they may cause:

- A. Hypercalcemia
- B. Hypermagnesemia
- C. Hypernatremia
- D. Hypokalemia

Answer: B. Hypermagnesemia

Q18. Which of the following is NOT an ideal property of an antacid?

- A. High acid-neutralizing capacity
- B. Non-toxic and non-irritant
- C. Produces acid rebound after neutralization
- D. Does not interfere with digestion

Answer: C. Produces acid rebound after neutralization

Q19. The major advantage of combining aluminium hydroxide with magnesium hydroxide in an antacid formulation is that it:

- A. Increases gastric acid secretion.
- B. Prevents carbon dioxide formation.
- C. Balances the gastrointestinal adverse effects of both drugs while providing effective acid neutralization.
- D. Converts the formulation into a systemic antacid.

Answer: C. Balances the gastrointestinal adverse effects of both drugs while providing effective acid neutralization.

Q20. Which of the following antacids is most suitable for rapid relief of heartburn but is generally NOT recommended for long-term therapy due to the risk of systemic alkalosis?

- A. Aluminium hydroxide gel
- B. Magnesium trisilicate
- C. Sodium bicarbonate
- D. Magnesium hydroxide

Answer: C. Sodium bicarbonate

Agents Promoting Bowel Movements (Laxatives & Cathartics)

Q21. Magnesium hydroxide acts as a laxative by:

- A. Stimulating gastric acid secretion
- B. Increasing intestinal osmotic pressure and retaining water
- C. Inhibiting intestinal motility
- D. Neutralizing bile salts

Answer: B. Increasing intestinal osmotic pressure and retaining water

Q22. Magnesium hydroxide is commonly known as:

- A. Epsom salt
- B. Milk of Magnesia
- C. Rochelle salt
- D. Glauber's salt

Answer: B. Milk of Magnesia

Q23. Sodium orthophosphate promotes bowel movement primarily by:

- A. Stimulating intestinal nerve endings directly
- B. Increasing osmotic pressure in the intestinal lumen
- C. Lubricating the intestinal wall
- D. Inhibiting water absorption from the intestine

Answer: B. Increasing osmotic pressure in the intestinal lumen

Q24. Sodium potassium tartrate is also known as:

- A. Milk of Magnesia
- B. Rochelle salt
- C. Epsom salt
- D. Baking soda

Answer: B. Rochelle salt

Q25. Which of the following is NOT a saline cathartic?

- A. Magnesium hydroxide
- B. Sodium orthophosphate
- C. Sodium potassium tartrate
- D. Aluminium hydroxide gel

Answer: D. Aluminium hydroxide gel

Q26. Magnesium trisilicate is mainly used as:

- A. Acidifier
- B. Antimicrobial
- C. Non-systemic antacid
- D. Radiopharmaceutical

Answer: C. Non-systemic antacid

Q27. The prolonged antacid action of magnesium trisilicate is mainly due to:

- A. Rapid absorption from the stomach
- B. Slow reaction with gastric hydrochloric acid and formation of colloidal silica
- C. Production of carbon dioxide
- D. Complete systemic absorption

Answer: B. Slow reaction with gastric hydrochloric acid and formation of colloidal silica

Q28. Which adverse effect is most commonly associated with magnesium-containing antacids?

- A. Constipation
- B. Diarrhoea
- C. Hypertension
- D. Hyperglycaemia

Answer: B. Diarrhoea

Q29. A patient with chronic constipation and hyperacidity would most likely benefit from which of the following?

- A. Aluminium hydroxide gel alone
- B. Magnesium hydroxide alone
- C. Sodium bicarbonate alone
- D. Dilute hydrochloric acid

Answer: B. Magnesium hydroxide alone

Antimicrobials

Q30. The primary mechanism of action of inorganic antimicrobial agents is to:

- A. Inhibit protein synthesis only
- B. Destroy or inhibit microorganisms by oxidation, halogenation, or protein precipitation

- C. Stimulate antibody production
- D. Increase gastric acidity

Answer: B. Destroy or inhibit microorganisms by oxidation, halogenation, or protein

Q31. Which of the following is an oxidizing antimicrobial agent?

- A. Boric acid
- B. Potassium permanganate
- C. Sodium bicarbonate
- D. Aluminium hydroxide

Answer: B. Potassium permanganate

Q32. Potassium permanganate exhibits its antimicrobial action mainly by:

- A. Protein synthesis inhibition
- B. Releasing nascent oxygen that oxidizes cellular components of microorganisms
- C. Inhibiting DNA replication
- D. Neutralizing bacterial toxins

Answer: B. Releasing nascent oxygen that oxidizes cellular components of microorganisms

Q33. Dilute solutions of potassium permanganate are commonly used for:

- A. Treatment of peptic ulcer
- B. Cleansing infected wounds and ulcers
- C. Intravenous infusion
- D. Neutralizing gastric acid

Answer: B. Cleansing infected wounds and ulcers

Q34. Boric acid acts primarily as a:

- A. Strong oxidizing agent
- B. Mild antiseptic and buffering agent
- C. Systemic antibiotic
- D. Antacid

Answer: B. Mild antiseptic and buffering agent

Q35. Hydrogen peroxide exerts its antimicrobial effect by:

- A. Releasing iodine
- B. Liberating oxygen in the presence of catalase, producing an oxidizing action
- C. Lowering tissue pH
- D. Precipitating proteins directly

Answer: B. Liberating oxygen in the presence of catalase, producing an oxidizing action

Q36. Which concentration of hydrogen peroxide solution is commonly used as an antiseptic?

- A. 0.03% w/v
- B. 3% w/v
- C. 10% w/v
- D. 30% w/v

Answer: B. 3% w/v

Q37. Chlorinated lime owes its antimicrobial activity mainly to the release of:

- A. Hydrogen peroxide
- B. Available chlorine (hypochlorous acid in solution)
- C. Sulfur dioxide
- D. Ozone

Answer: B. Available chlorine (hypochlorous acid in solution)

Q38. Which iodine preparation is widely used as a skin antiseptic before surgical procedures?

- A. Sodium iodide solution
- B. Tincture of iodine / Povidone-iodine solution
- C. Lugol's solution only for external use
- D. Potassium iodide solution

Answer: B. Tincture of iodine / Povidone-iodine solution

Q39. A disinfectant is required for disinfecting contaminated water because it provides a sustained release of available chlorine. Which of the following is the most suitable choice?

- A. Boric acid
- B. Chlorinated lime
- C. Magnesium trisilicate
- D. Sodium bicarbonate

Answer: B. Chlorinated lime

Radiopharmaceuticals

Q40. A radiopharmaceutical is defined as:

- A. A drug used only for radiation therapy
- B. A pharmaceutical preparation containing a radioactive isotope used for diagnosis or therapy
- C. A disinfectant containing radioactive material
- D. A contrast agent used in X-ray imaging

Answer: B. A pharmaceutical preparation containing a radioactive isotope used for diagnosis or therapy

Q41. The spontaneous emission of radiation from an unstable atomic nucleus is known as:

- A. Oxidation
- B. Radioactivity
- C. Ionization
- D. Fluorescence

Answer: B. Radioactivity

Q42. Which radioisotope is most widely used in nuclear medicine for diagnostic imaging because of its short half-life and gamma-ray emission?

- A. Cobalt-60
- B. Phosphorus-32
- C. Technetium-99m
- D. Sodium iodide I-131

Answer: C. Technetium-99m

Q43. Sodium iodide I-131 is primarily used in the diagnosis and treatment of disorders of the:

- A. Liver
- B. Kidney
- C. Thyroid gland
- D. Heart

Answer: C. Thyroid gland

Q44. Which radioisotope is mainly employed in radiotherapy for the treatment of malignant tumors?

- A. Technetium-99m
- B. Cobalt-60
- C. Sodium chloride-24
- D. Carbon-14

Answer: B. Cobalt-60

Q45. Phosphorus-32 is mainly used for the treatment of:

- A. Hyperthyroidism
- B. Polycythemia vera and certain blood disorders
- C. Bone fractures
- D. Diabetes mellitus

Answer: B. Polycythemia vera and certain blood disorders

Q46. Which type of radiation emitted by Technetium-99m makes it particularly suitable for diagnostic imaging?

- A. Alpha radiation
- B. Beta radiation
- C. Gamma radiation
- D. Neutron radiation

Answer: C. Gamma radiation

Q47. Which of the following is the most appropriate precaution while handling radiopharmaceuticals?

- A. Store them in transparent plastic containers exposed to sunlight.
- B. Minimize exposure time, maximize distance, and use appropriate shielding.
- C. Keep radioactive materials in open containers for ventilation.
- D. Dispose of radioactive waste with general laboratory waste.

Answer: B. Minimize exposure time, maximize distance, and use appropriate shielding.

Q48. Radioactive waste generated in hospitals should be:

- A. Disposed of with municipal waste.
- B. Poured directly into the drainage system.
- C. Managed according to approved radiation safety and regulatory guidelines.
- D. Burned in an open environment.

Answer: C. Managed according to approved radiation safety and regulatory guidelines.

Q49. A patient is scheduled for a thyroid uptake scan. Which radiopharmaceutical would be the most appropriate choice?

- A. Cobalt-60
- B. Technetium-99m sulfur colloid
- C. Sodium iodide I-131
- D. Phosphorus-32

Answer: C. Sodium iodide I-131

Short Answer Type Questions (Objective type questions):

1. Define acidifiers and mention one pharmaceutical use of sodium acid phosphate.
2. State the therapeutic use of dilute hydrochloric acid.
3. List the ideal properties of an antacid.
4. Explain why combinations of antacids are preferred over single antacids.
5. State the mechanism of action of sodium bicarbonate as an antacid.
6. Mention two advantages and two disadvantages of aluminium hydroxide gel.
7. Explain the mechanism by which magnesium hydroxide promotes bowel movements.
8. State the pharmaceutical use of sodium orthophosphate.
9. Write the synonym and one use of sodium potassium tartrate.
10. State the mechanism of action of magnesium trisilicate as an antacid.
11. Classify antimicrobial agents with suitable examples.
12. Explain the antimicrobial mechanism of potassium permanganate.
13. State two pharmaceutical uses of boric acid.
14. Describe the antimicrobial action of hydrogen peroxide.
15. State the pharmaceutical application of chlorinated lime.
16. Mention the pharmaceutical preparations of iodine and their uses.
17. Define radioactivity and radiopharmaceuticals.
18. State one diagnostic and one therapeutic application of Technetium-99m and Cobalt-60.

Long Answer Type Questions

1. Explain the importance of safe handling and storage of radiopharmaceuticals.
2. Justify the need for proper disposal of radiopharmaceuticals according to regulatory guidelines.
3. Discuss acidifiers with reference to sodium acid phosphate and dilute hydrochloric acid, including their preparation, properties, mechanism of action, uses, and storage.
4. Explain the ideal properties of antacids and discuss sodium bicarbonate and aluminium hydroxide gel with respect to preparation, properties, mechanism of action, uses, storage, and pharmaceutical importance.
5. Explain the classification of agents promoting bowel movements and discuss magnesium hydroxide, sodium orthophosphate, sodium potassium tartrate, and magnesium trisilicate with suitable mechanisms and pharmaceutical applications.

6. Discuss the mechanism of action and classification of antimicrobial agents. Explain the pharmaceutical importance of potassium permanganate, boric acid, hydrogen peroxide, chlorinated lime, and iodine preparations.
7. Describe the preparation, properties, uses, storage, and antimicrobial mechanism of hydrogen peroxide and chlorinated lime.
8. Explain the basics of radioactivity and discuss the pharmaceutical applications of Sodium Iodide I-131, Technetium-99m, Cobalt-60, and Phosphorus-32.
9. Evaluate the importance of safe handling, storage, transportation, and disposal of radiopharmaceuticals with reference to regulatory safety guidelines.
10. Analyze the selection of gastrointestinal agents, antimicrobial agents, and radiopharmaceuticals for different pharmaceutical and clinical applications with suitable justification.