APPLICATIONS OF ADSORPTION

2.6 GENERAL APPLICATIONS OF ADSORPTION

2.7 ROLE OF ADSORBENTS

Role of adsorbent in catalysis (or) Contact Theory

Activated carbon in pollution abatement

2.6 GENERAL APPLICATIONS OF ADSORPTION

1. Activated charcoal is used in gas masks, which adsorbs poisonous gases (like CO) in coal minesand it is employed in both military and industrial purposes.
2. Activated charcoal is used for removing colouring matter from solutions. Silica gel and alumina gel are used as adsorbent for removing moisture and for controlling humidity of room.
3. Silica gel is used for drying air used in blast furnace.
4. Fullers' earth is used in large quantities for refining petroleum and vegetable oil by using Ni catalyst, which adsorbs unwanted materials.
5. Silica gel and alumina gel act as an adsorbent which is extensively used in cracking of heavy oil vapours to yield high quality petrol.
6. Arsenic poisoning from the body is removed by using colloidal ferric hydroxide, which adsorbsarsenic poison and retains it and can be removed from the body by vomiting.
7. Softening of hard water can be done based on the principle of adsorption using ion-exchange resins.
8. Sulphide ores (PbS, ZnS) are freed from silica and other earthy matter by forth flotation process.(Oil adsorbs sulphide ores only)
9. The phenomenon of adsorption is useful in heterogeneous catalysis, in which the molecules areadsorbed on the surface of solid catalyst and form activated complex. Then it decomposes to give product.
   Example: Manufacture of SO_3 by contact process.
10. Mordent's are used in dying industry, which adsorb the dye particles (colouring matter) withoutattaching to the fabrics.
11. Adsorption process is used in production of vaccum by using activated charcoal in Dewar's flask.
12. A layer of stearic acid is spread over water in lakes and reservoirs during summer as theadsorbed stearic acid on the surface of water reduces the loss of water by evaporation.

2.7 ROLE OF ADSORBENTS

ROLE OF ADSORBENT IN CATALYSIS (or) CONTACT THEROY

(1) In heterogeneous catalysis

Adsorption or contact theory explains the mechanism of a reaction between two gases catalyzed bya solid, heterogeneous catalyst. Here, the catalyst functions by adsorption of reactant molecules on its surface forming an activated complex. This complex decomposes giving rise to the productswhich are readily desorbed.

Example: Hydrogenation of ethylene in the presence of finely divided nickel as catalyst.

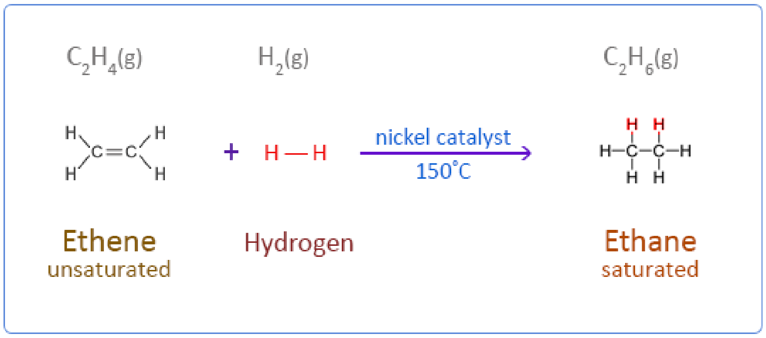

Figure 2.7.1 Hydrogenation of ethylene

[Source: http://www.passmyexams.co.uk/GCSE/chemistry/alkenes-and-hydrogen-reaction.html]

STEP 1: Adsorption of hydrogen gas on nickel

The surface of the solid catalyst has certain isolated active centers, due to unsaturation of valencies.The gaseous hydrogen molecules are adsorbed at the active centre of the nickel surface either by Physisorption or by chemisorption. If the temperature is sufficiently high, the gases get chemisorbedon the surface.

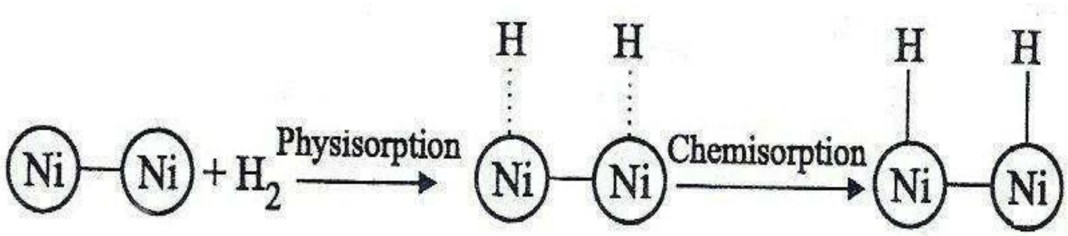

Figure 2.7.2 Adsorption of hydrogen gas on nickel

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.25]

STEP 2: Formation of activated complex

The activated hydrogen molecule reacts with ethylene gas to form an activated complex. This activated complex is unstable, which decomposes giving rise to the products that are readily desorbed.

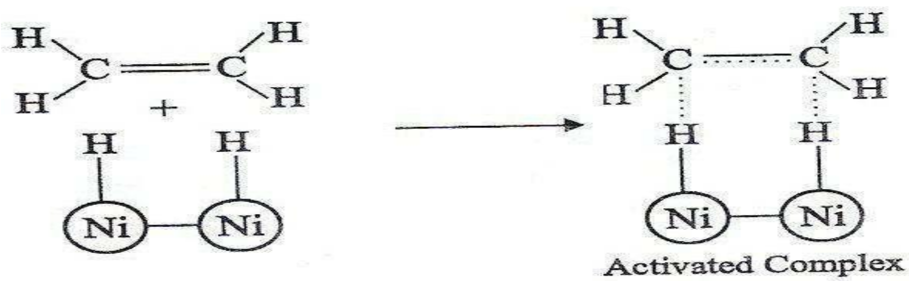

Figure 2.7.3 Formation of activated complex

[Source: "Chemistry for Technologists" by Dr. Ravikrishnan A, Page2.25]

STEP 3: Decomposition of activated complex

The activated complex breaks to form the products. The separated particles of the products boundto the catalyst surface by partial chemical bonds.

Figure 2.7.4 Decomposition of activated complex

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.26]

STEP 4: Desorption of products

The Ni catalyst is desorbed from the surface and gives stable ethane gas.

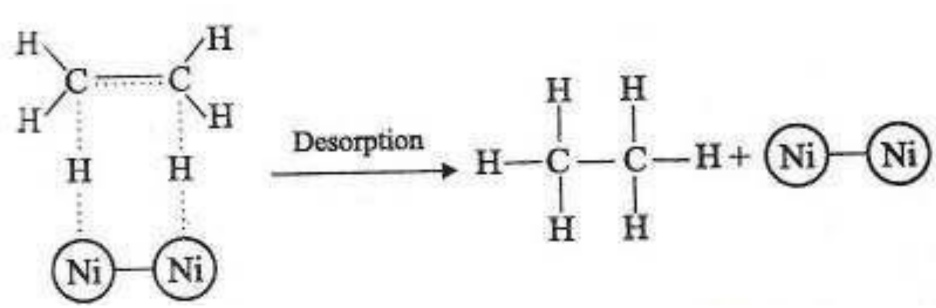

Figure 2.7.5 Desorption of products

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.26]

(2) The catalyst is more efficient in finely divided state

When the subdivision on fineness of the catalyst increases, the free surface area gets increased.

Thereby free valencies (or) active centers, which are responsible for the adsorption of reactant molecules increases, consequently the activity of the catalyst are also increased.

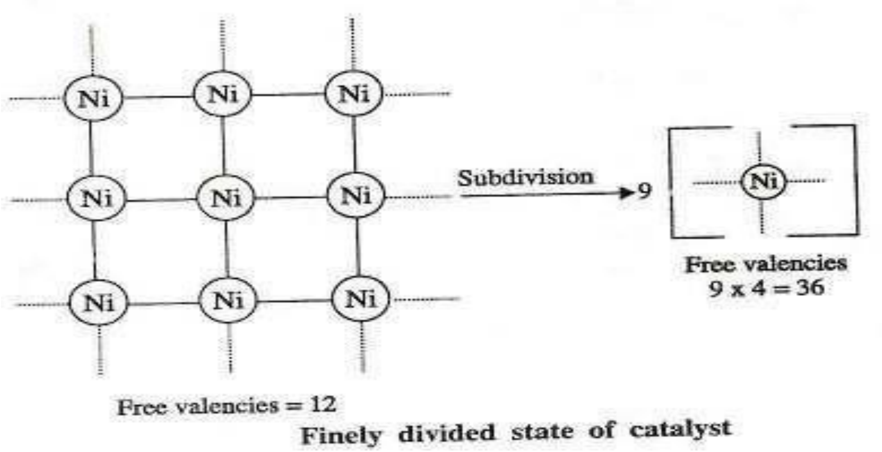

Figure 2.7.6 Catalyst is more efficient in finely divided state

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.27]

(3)Enhanced activity of a rough surfaced catalyst

Rough surface of a catalyst possesses cracks, peaks, corners, etc., consequently the surface havelarger number of active centre's, which increases the rate of adsorption.

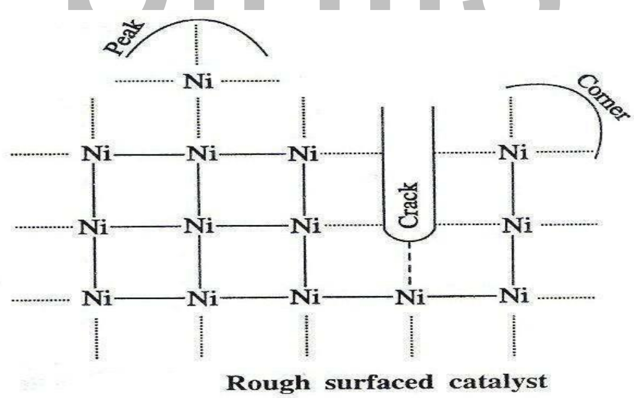

Figure 2.7.7 Enhanced activity of a rough surfaced catalyst

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.27]

(4)Action of promoters

Promoters are defined as, "the substances which increase the adsorption capacity or activity of a catalyst". The action of promoter is explained as follows:

(i)Change of lattice spacing

Promoters increase the spaces between the catalyst particles, so the adsorbed molecules are further weakened and cleaved. This makes the reaction to go fast.

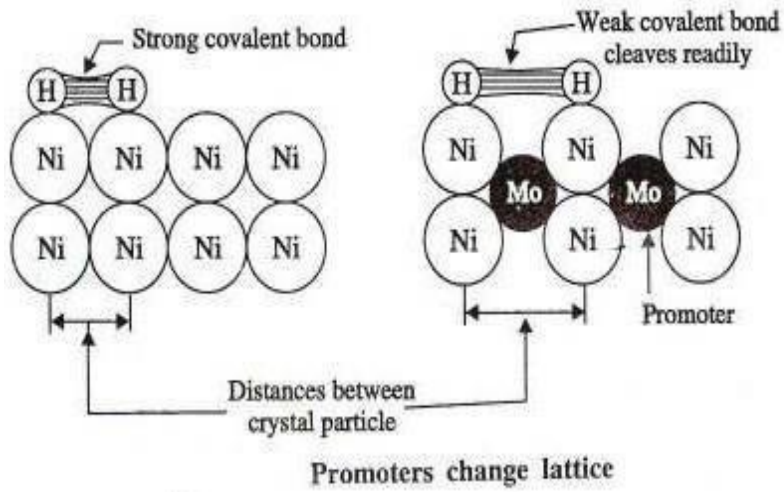

Figure 2.7.8 Change of lattice spacing

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.28]

(ii) Increase of peaks and cracks

Promoters increase the peaks and cracks on the catalyst surface. This increases the concentration ofreactant molecules and hence the rate of the reaction.

(5)Action of catalytic poisons

"A substance which destroys the activity of the catalyst to accelerate the reaction" is known as catalytic poisoning.

(e.g) The Pt catalyst used in the oxidation of H_2 is poisoned by CO.

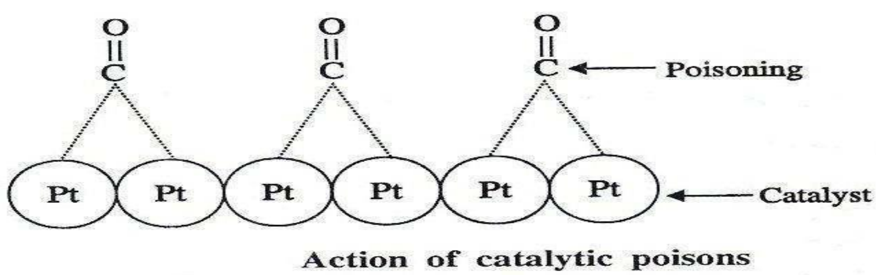

Figure 2.7.9 catalytic poisons

[Source: "Chemistry for Technologists" by Dr.Ravikrishnan A, Page2.29]

The number of free valancies (or) active centers of the catalyst is reduced by the preferential adsorption of the poisonous substances. So, the rate of reaction decreases.

(6) Specific action of catalyst

The adsorption depends on the nature of both the adsorbent (catalyst) and the adsorbate (reactants). So, different catalyst cannot possess the same affinity for the same reactant. Hence, the action of the catalyst is also specific.

(e.g) Ethanol gives ethylene in the presence of hot Al_2O_3, but with hot copper it gives acetaldehyde.

ACTIVATED CARBON IN POLLUTION ABATEMENT

Among the various adsorbents, in pollution abatement of air and waste water, activated carbon is the most commonly used adsorbent because it has a large surface area per unit weight (or) unit volume of solid.

Treatment of Polluted Water and Air

Polluted water and air can be treated by using the following two types of activated carbons.

1) Granular Activated Carbon (GAC)
2) Powdered Activated Carbon (PAC)

1. Using Granular Activated Carbon (GAC)

A fixed - bed activated-carbon contactors (column) is often used for contacting polluted water (or) air with GAC. It can be operated singly, in series (or) in paralle1. Several types of fixed-bed activated - carbon contactors are used in the treatment of polluted water (or) air, of which the followings are important.

1. Down flow fixed-bed carbon contactors.
2. Up flow fixed-bed carbon contactors.

(a) Down flow fixed-bed Carbon Contactors

Down flow fixed-bed carbon contactors usually consist of two (or) three columns operated in series(or) in parallel as shown.

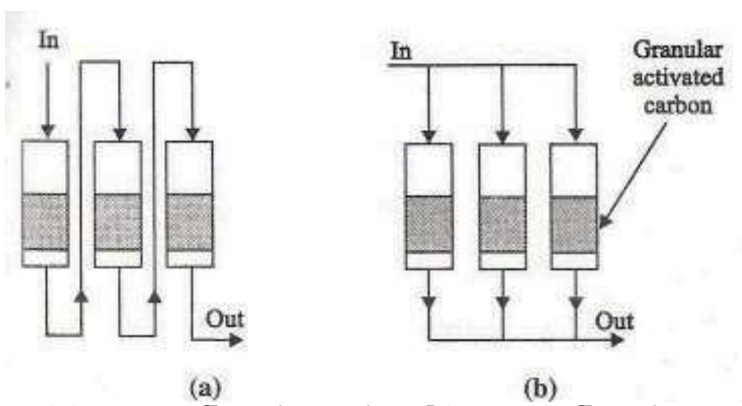

Figure 2.7.10 (a) Down flow in series (b) Down flow in parallel

[Source:https://www.bharathuniv.ac.in/colleges1/downloads/courseware_ece/notes/2%20BCH201%20%20-%20chemistry%202%20-%20NT.pdf]

The water (or) air is applied to the top of the column and withdrawn at the bottom. The activatedcarbon is held in place with an under drain system at the bottom of the column. Provision for back washing and surface washing is usually necessary to limit the headless build up due to the removal of particulate material within the carbon column.

Advantages

Adsorption of organic materials and filtration of suspended solids are accompanied in a single step.

Disadvantages

- Down flow filters may require more washing because of the accumulation material on thesurface of the contactor.
- Plugging of carbon pores may require premature removal of the carbon for regenerationthereby decreasing the useful life of the carbon.

(b) Up flow fixed-bed Carbon Contactors

In the up flow fixed-bed columns, the polluted water (or) air moves upward from the base of thecolumn as shown.

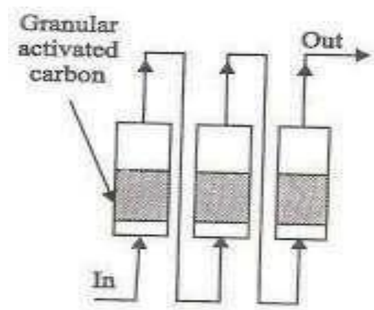

Figure 2.7.11 Up flow expanded in series

[Source:https://www.bharathuniv.ac.in/colleges1/downloads/courseware_ece/notes/2%20BCH201%20%20-%20chemistry%202%20-%20NT.pdf]

Advantages

As the carbon adsorbs organic materials, the apparent density of the carbon particles increases and encourages rnigration of the heavier or spent carbon downward.

Disadvantage

Up flow columns may have more carbon fines in the effluent than down flow columns, because up flow tends to expand, not compress, the carbon. Bed expansion allows the fines to escape through passage ways created by the expanded bed.

2. Using Powdered Activated Carbon (PAC)

In this method powdered activated carbon (PAC) is added directly into the effluent coming out from the various biological treatment processes.

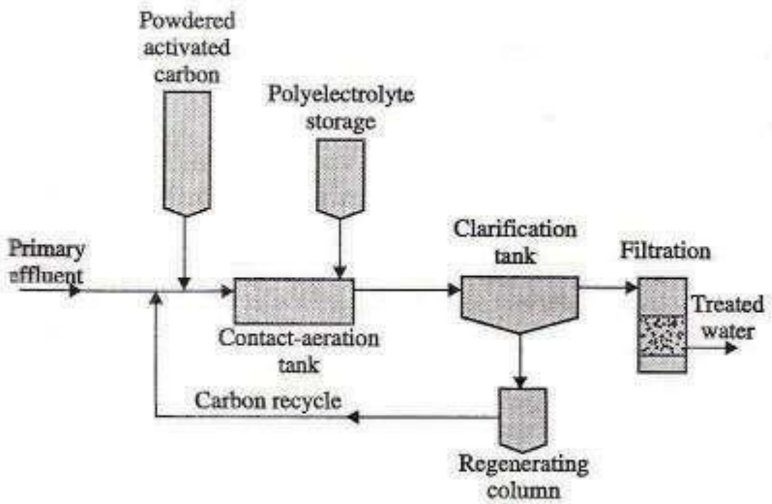

Figure 2.7.12 Flow diagram of activated-sludge process

[Source:https://www.bharathuniv.ac.in/colleges1/downloads/courseware_ece/notes/2%20BCH201 %20%20-%20chemistry%202%20-%20NT.pdf]

The effluent, coming out from the biological treatment plant, is mixed with PAC and a coagulant(polyelectrolyte) in a contact-aeration tank. After some time, the effluent is allowed to store in a clarification tank, where the carbon particles get settled at the bottom of the tank Since the carbon particles are very fine, a coagulant such as polyelectrolyte is added to aid the removal of the carbon particles. The spent carbon is regenerated by passing it into the regenerating column and is used again for the process. Finally, the water (effluent) is filtered by passing it through the filtration column.