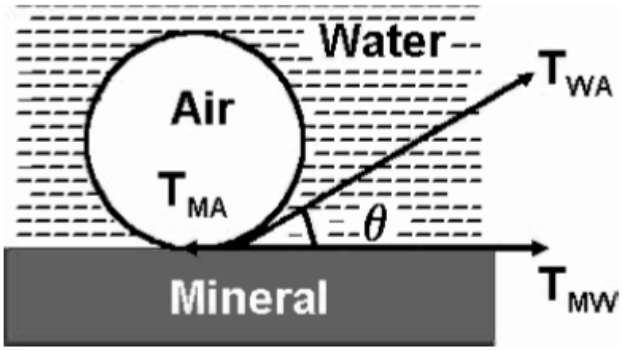
Contact angle (θ) is an angle of contact of an air bubble with the surface of a solid measured across the water (Figure 16.2). It is a convenient measure of the forces of adhesion between the bubble and the solid surface. The contact angle marks the position of equilibrium between the solid-water and water-air surfaces on a wetted surface i.e., it is the position of equilibrium between three tension forces; the surface tension of water TWA, surface tension of solid mineral TMA and interfacial tension TMW between the solid mineral and water.

If the surface tension of the solid mineral TMA is more, the water is pulled over the solid till an acute angle θ is reached, when the component of water tension TWA together with the interfacial tension TMW is sufficient to bring about equilibrium. Under these conditions, the solid shows a preference for water. If the interfacial tension TMW is greater, the water will be drawn back and an obtuse angle will form. Under these conditions the solid has a preference for air.



Contact angle

When the solid shows affinity for water TMA = TMW + TWA cos θ 1

When the solid shows affinity for air TMW = TMA + TWA cos θ 2

Therefore, TWA cos θ is a measure of degree of wetting. When the contact angle is nil, θ = 0, cos θ = 1, the degree of wetting is maximum. When the contact angle is 180o, θ = 180o, cos θ = −1, the water will contract its extent and the degree of wetting is at a minimum. Since there is always some adhesion between solids and liquids in contact, there is no such thing as complete non-wettability, i.e., a contact angle of 180o. Adherence of the mineral particle to the air bubble depends on contact angle. As the contact angle increases, adherence increases and hence

floatability increases. Minerals with high contact angle are called aerophilic (hydrophobic), i.e. they have higher affinity for air than for water. Most minerals are aerophobic (hydrophilic) in their natural state. To make the valuable mineral particles aerophilic, reagents called collectors are added to the pulp which adsorb on mineral surfaces, increases contact angle and facilitates bubble attachment. Many freshly formed mineral surfaces exhibit a natural contact angle of a few degrees. Graphite and some coals have high contact angles to float without aid of a collector. They are said to have natural floatability.

The following are the methods adopted in practice:

1- To make the mineral particles adhere to the air bubble whilst it is rising through the pulp, the mineral particles are treated with suitable chemicals to acquire adhering properties.

2- To prevent the air bubble from collapse, some other chemicals are used to prevent the collapsing of the air bubble or in other words to increase the life of the air bubble.

The required mineral particles after adhering to the air bubble float to the surface along with the air bubble. The aggregation of several such mineral adhered air-bubbles forms the froth on the surface of the pulp , Hence this operation of mineral separation is named Froth flotation.

Most of minerals have clean surface without pollution from accompaniment composites throw formation processing or deposit of this rock formation. This surface has adhere properties when it is wetted in water instead of air, organic material such as kerosene , paraffin, and fewest of another minerals such as coal that is have adhere in air instead of water, this materials are collected at the interval surface between air and water. This material have non polarization, or non- polarization surface haven't electrical charge with the around media.

The water particles have electrical charge (polarization particles) so that they are trend to adhere with metal surface, so that by some treated or chemical reactions can covered the polarization mineral surface by thin film from non- polarization composition to keep them from adhere in water and allow and forced them to adhere in air bubbles finely they are floated on surface.

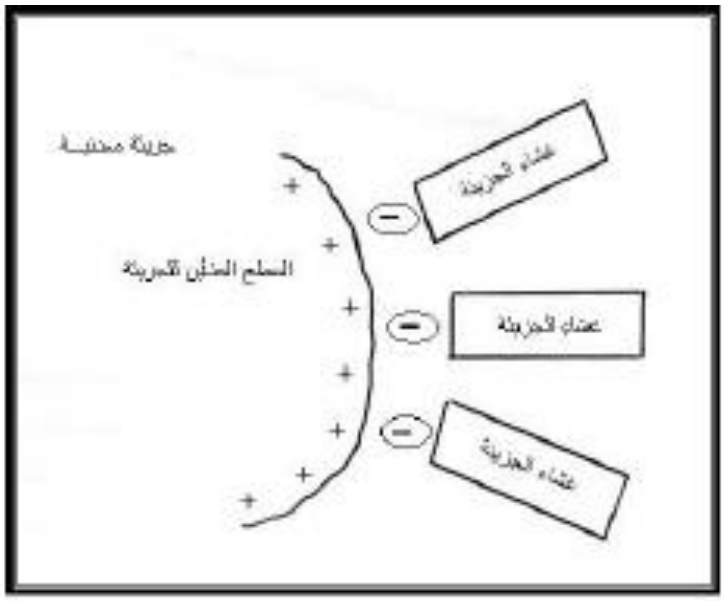
This method depended on when have one composition with mixed from polarization material and this is the suitable efficient method for mineral separation.

This added composition called catalyst it is an chemical reagent used to increase the efficient of separate process it is form a film keep particle surface from adhere in water, and lead to isolated the floated minerals in top of cell flotation cell and the non-floated particles in bottom, for this purpose used different type from chemical catalyst such as collectors, frothiers, depressants, activators, and deactivators.

The collector is the important materials used in this method it form film have electrical charge opposite the charge of material surface and the other side of the film facing to water surface have an equal charge.

Table 12.33. Classification of materials according to their flotation properties (after Eigeles, 1964)

Class	Example	Applied collectors
Non-metals and solids with significant natural hydrophobicity	sulfur, graphite, coal, talc	hydrocarbons, nonionic liquids insoluble in aqueous
Native metals and sulfides	gold, chalcocite chalcopyrite, galena sphalerite	xanthates, aerofloats
Oxidized minerals of non-ferrous metals	cerusite, smithsonite malachite, tenorite, cuprite	xanthates (after sulfidization), anionic and cationic
Oxides, hydroxides and silicates	hematite, ilmenite corundum, cassiterite chromite, feldspars kaolinite	anionic and cationic (with and without activation using metal ions)
Sparingly soluble salts	fluorite, barite, calcite, apatite, dolomite	anionic and cationic
Soluble salts	halite, silvinite, carnalite, kieserite	cationic, seldom anionic



شكل رقم (7-22) مخطط يوضح الغشاء الجامد كفاصل السطح المعني

There is many condition must applied when used floatation cell in mineral separation process to implementing good extraction efficient :

1- preparation of the slurry and liquid in stable velocity.

2- given enough time for complete reaction between mineral particles and reagent.

3- product enough amount of bubbles have nearest size to the particles mineral require to floated.

4- allow to form froth from the floated particles mineral quietly to can remove it easily.

5- remove the froth constantly and good efficient to allow formed another forth.

The size of particles that able to floated in floating process depended on intensity of particles for example the particle size of coal that separated in this method is about (2mm) if the intensity of coal is (1400 kg/m^3) the intensity the intensity of particles size of (5000kg/m^3) so particles size that able to floated are (200 mile micron). The mixed that feed inside floatation cell to a fine size from particles that required to separate while the particles that undesirable must be heavier to immerse and pull out

with gangue. So that the size and intensity of particles is very important when use this method to separated minerals.

The floating is done inside big metal tank content chemical liquid with minerals mixing and passed bubbles from the bottom of tank towards mixed and it must to give enough time (about 15 sec.) to the bubble to adhere with the desirable particle and force it to foaled toward surface, there is some undesirable particles floated and deal to decrease in separation efficient, but can get a good separation efficient by sequential series from tanks or flotation cells pass the minerals mix through them sequentially, there is ability to separate more than one mineral by sequential series of mineral processes example if we have mix of minerals content galena (PbS) chalcobyrite ($CuFeS_2$), sphalerite (FeZnS), pyrite (FeS_2), with connection material (SiO_2), first galena will separated and the other minerals separate sequentially depended on their intensity such as chalcobyrite, sphalerite, pyrite.

The liquids that used in floated cell usually are sea water or salty water and air bubbles because it cheap and low cost.

2-Leaching process

most of mineral in natural can treated by chemical materials selectivity, it can separate one of the desirable elements from the other in minerals such as soluble compounds. The mineral that can separate it by leaching process is boron B, copper Cu , aluminum Al, magnesium Mg , nickel Ni, tungsten W, gold Au, silver Ag, zinc, uranium U, sodium Na.

There are three type of leaching process:

1-insitu leaching

2-tank leaching

3-Dump leaching

1-insitu leaching

Some rocks content minerals composition dissolve in water, this content can dissolved by passing water through rock porous, example dissolve sodium chloride in water to extract halite (sodium chloride salt), also dissolved potassium chloride and uranium , after the mining process and extract the ores from their place leaching process done by explosion rocks around the mining Chanel and passing water to dissolved heavy mineral remind such as copper and uranium and pull it out and separate the minerals from it.

2-tank leaching

In this method rocks crushing in to specific size to cover and exposure the mineral particles to the chemical solution that is used in the process, by but the mix of mineral in rocks inside big tanks and treated by passing pass chemical solution and give the particles enough time to dissolved and form another compounds dissolved in the solution pulled out of tank to treated for separation and extracted the dissolved composition. For example extracted the gold that compound naturally with silicate by treated with potassium cyanide (KCN) the silicates are remains while the gold is dissolve to form complex compound as the following equation:

$$2Au + \frac{1}{2}O_2 + 4KCN + K_2O \longrightarrow 2K\{Au(CN)_2\} + 2KOH$$

the solution are filtered and add to it (zinc powder) that works to gold deposition.

Another example is extracted the copper from ore by dissolve it in diluted sulfuric acid to form soluble copper sulfate then the copper is separated by filtering.

On of the common process to used leaching tank is **(bayer process) for product the alumina (Al_2O_3) from boxite (Al_2O_3 . n H_2O)** that is found with clay, silica, iron, and magnessium deposites**.** The treatment of bauxite is done by pass (caustic soda) under spesific pressure and high tempruture about (430) kelven to form saturated solution in alumina and sodium after cold it deal to deposition of aluminum hydroxide and soduim hydroxide, aluminuim composition are separated by feltiring and exposed to high tempretures to turn into aluminum oxide (Al_2O_3).

3-Dump leaching

It is an easier technical to separate some mineral from gangue, where is possible to exists few concentrated ratio in minerals in gangue of mining and residue of extraction plants that is ejected out such as aggregate, this aggregate able to have maximum benefit from it and extract the remain of minerals composition in cheap and easier method by splatter some chemical material and solution on this aggregate to work on dissolve some minerals such as remain copper and pull out this soluble to separate the copper. This method used some time while remove the rock cover from mine content a sulfates minerals, and cumulated the rocks and splatter it in sweet water to help to the reaction between sulfate and oxygen air to product soluble sulfate oxides in water and form sulfuric acid that work on dissolve another minerals in rock composition.