This invention relates generally to the successful production of electro-plating with metals such as tungsten, thorium, molybdenum, aluminum, etc., which are difficult to reduce electrolytically from an aqueous solution of their salts which may be considered available for the purpose, partly because they have a high affinity for the oxygen of the water and that liberated at the anode by the breaking down of their salts by electrolysis when in solution in the bath, and which metals, therefore, have not been usable heretofore for plating by the usual process of electrolysis of an aqueous bath. The present invention more particularly comprises a specific adaptation of such process for obtaining a dense, substantially pure plated layer of metallic tungsten deposited from an aqueous bath on any suitable body as a cathode.

Heretofore successful electro-plating with tungsten from an aqueous bath has not been found possible because the tungsten has not been deposited from any such bath in pure metallic form, but (largely because of its tendency to reoxidize) only as a sub-oxide (WO₃, or some lower oxide), and such deposit, besides being metallurgically impure, has not adhered firmly to the cathode base. So far as I know no substantially pure tungsten plating has ever been produced prior to my present invention, and though it has been stated in the technical literature of the art that tungsten plating has been produced by using a fused bath containing a tungsten compound, and also by using non-aqueous organic solutions for the bath, no such process has ever gone into commercial use, to the best of my knowledge and belief, and my most careful repetitions of the prior described processes have not resulted in the deposition of any pure metallic tungsten. Furthermore, even if some form of fused bath process could be made to produce pure tungsten plating, it would be very costly in operation and commercially impracticable for a variety of reasons. Thus, the cathode or “work” used in such fused bath must be one having a high melting point, higher than that at which the bath is maintained. Consequently brass and other common metals and alloys desirable for use as the base to be plated can not be employed in any such process which must be maintained at a temperature of at least 800° C., in the case of the sodium chloride bath, which is the most practicable of those heretofore suggested, whether or not tungsten plating can be done in a bath of non-aqueous organic solution, it has been frequently stated in recent patent specifications and technical papers that aqueous baths can not be used successfully for this purpose.

In my present invention I have, generally speaking, overcome these difficulties heretofore encountered in attempts to plate from an aqueous bath by the use of all or some of the following expedients. First, I interpose a porous diaphragm between the electrodes, preferably immersing in the bath a porous cup of some material insoluble in the bath, and placing the cathode in said cup. Second, I preferably add sodium hydroxide (NaOH) or potassium hydroxide to the bath. If then the raw material used is tungstic acid this causes the tungsten to be present in the bath in the form of a tungstate, such as sodium tungstate or potassium tungstate, the former, especially, being much more soluble in aqueous baths than are any of the tungsten oxides usually employed as the raw material. Such tungstates may thus conveniently be formed in situ by introducing tungstic acid (WO₃) and sodium hydroxide (NaOH) as the raw materials and allowing the tungstate to be produced by the resulting reactions then occurring. Third, I add some water soluble carbonaceous material (preferably dextrose, starch, sugar or some other soluble carbohydrate) to the bath, which serves as a “buffer” in the sodium hydroxide solution in the well known way, decomposing gradually and thereby forming organic acids which serve to slightly reduce the original alkalinity of the bath. Fourth, I adjust the current density on the cathode at an amount which will produce a fairly copious evolution of hydrogen which appears in the form of bubbles at the surface of the bath, which procedure is in direct opposition to the standard plating practice.

I may also use a minor proportion of acid
in the bath, preferably hydrochloric acid, though this is not essential. In such case the amount of acid should not be sufficient to destroy the alkalinity of the bath. Hydrochloric acid seems to be preferable wherever a tungsten anode is used, probably because the liberated chlorine tends to prevent polarization of the anode as the chlorine ions attack it readily and evenly, much the same as in nickel plating, where hydrochloric acid is often used to counteract polarization. The amount of such acid of whatever description must, however, be kept within well-defined limits. As the ultimate result desired is the liberation of chlorine in the bath, this may be obtained by simply adding sodium chloride (common salt) to the bath, in place of hydrochloric acid. This would have the added advantage of not disturbing the substantial alkalinity of the bath which it is essential to preserve.

I may secure the supply of the metal for plating by the breaking up in the bath of a salt of the metal, as when the sodium hydroxide combines with tungstic acid to form sodium tungstate, as described above, or the supply may be obtained by the corrosion of an anode of the pure metal, or by both expedients.

The carbohydrate is preferably employed in excess so as to avoid the necessity of constant renewals thereof, but the plating action goes on satisfactorily if only a trace is present, at least when plating with tungsten.

It has been determined that the effect of the dextrose is to decrease slightly the alkalinity of the hydroxide bath solution by its well-known action as a "buffer", producing a solution of lower pH number. Thus the pH value showing the hydrogen-ion concentration of a solution of 30 grams NaOH in a litre of water was found to be about 13.6, by the ammoneal electrode method of determination, and the showing was about the same after 30 grams WO₃ was added, but, on the addition of 30 grams of dextrose, the pH value fell to 14 and progressively thereafter decreased until, after fifteen minutes operation of the bath, it fell to 11.2. It has been found that the best plating action occurred when the pH value of the bath was about 12, and that an equally good plating action resulted when this pH value was secured by adding a sufficient further amount of WO₃ instead of adding the dextrose. Whether successful plating action is a result of the degree of alkalinity of the bath, produced by the above or some other method, or whether it is the result of the creation of one or more of the very complex and somewhat indefinitely determined compounds differing slightly from the normal tungstate, such as the para-tungstate or meta-tungstate, the presence of which is merely indicated by a given degree

of alkalinity of the bath, has not yet been determined.

The possible range of current density per unit of cathode surface immersed is quite wide. It may be as low as 5 amperes per square foot. The upper limit rises with the alkali concentration of the bath, and with concentrated solutions of that character may reach 200 amperes or more. The current density should always be sufficient to cause a liberation of numerous bubbles of hydrogen at the cathode. It has generally been considered bad practice to produce any such considerable evolution of hydrogen in plating with copper and other metals, not only because it involves a waste of current, but also because it has a deleterious effect in that it causes the deposition of a porous and non-adherent film of the plating metal. I have found, however, that in plating with tungsten and similar metals of the class to which my invention is applied the evolution at the cathode of a considerable quantity of hydrogen bubbles is necessary. Consequently, while the total current employed per unit of immersed cathode surface as above given may be within the standard ranges of copper plating, the "efficient" current, in the usual meaning of that term, actually employed in plating, is usually much less than that employed in previous practice, the balance, perhaps ninety per cent or more, being consumed in the evolution of the hydrogen.

The porous diaphragm is particularly useful when a carbon anode is used, as the copious liberation of oxygen at the anode rapidly decomposes the carbon, thus fouling the bath and the cathode surface with the finely divided carbon so produced unless this is prevented by the interposition of the porous diaphragm.

Another observed phenomenon which, on the contrary, (and in contradistinction of standard plating practice) indicates the production of perfect plating, is the foaming of the bath in the cup about the cathode. This is apparently caused by the action of the carbohydrate on the hydrogen bubbles, somewhat similar to the action of a soap solution in producing soap bubbles. If the bubbles so generated in the cup about the cathode are fine enough to produce a coherent layer of foam on the surface of the bath, it indicates that hydrogen is being liberated at the proper rate to ensure good plating.

I have found that a decided excess of caustic alkali is preferable rather than to rely on the conditions resulting from the formation of the normal salt, Na₂WO₄, of K₂WO₄. Forming the sodium salt, Na₂WO₄, in the bath will require only 80 grams of NaOH for every 282 grams of yellow oxide, WO₃. However, a bath made up with sodium tungstate and no excess sodium hydroxide does not operate quite satisfactorily. Accordingly, I
prefer to operate with a bath containing from 90 to 180 grams of NaOH for every 232 grams of WO₃ and also containing 10 to 100 grams of a carbohydrate, such as dextrose.

These proportions are based on a unit litre of bath volume. The best results so far have been obtained with a current density of about 20 to 30 amperes per square foot of cathode surface, and a temperature of bath of from 90 degrees to 90 degrees centigrade. The best results are obtained with the higher temperatures and the above described high concentration of the bath produced by the excess of the alkali constituent.

In carrying out one example of the said improved process, I may also proceed as follows: In about 75 cubic centimeters of water I place 75 grams of sodium hydroxide (NaOH), 51 grams of the yellow oxide of tungsten (WO₃), 60 grams of dextrose and 8 cubic centimeters of concentrated hydrochloric acid (HCl) of specific gravity of 1.18 and then add sufficient water to bring the volume up to one litre. The resulting litre of the solution is maintained at a temperature of 55 degrees centigrade and a current of 1.7 volts and 1.4 amperes passed through it from a tungsten anode (a treated wire slug) to a brass cathode plate having an immersed surface facing (including its two faces) of 5 square inches, this producing a current density of 40 amperes per square foot. The tungsten oxide is the commercial product of the characteristic known as tungstic acid, and need not be preliminarily washed. In about 20 minutes the cathode brass plate will be completely covered by a hard, gray, closely adherent deposit which has the characteristic appearance of pure metallic tungsten, and which I have determined by standard tests to consist of substantially pure tungsten.

As a further illustration of the possible modifications of the process as to the proportions of the constituents of the bath I will state a third example in which I obtained a satisfactory tungsten plating on a brass plate with 6 square inches of immersed surface in about 20 minutes by using a current density of 17.3 amperes per square foot, with a voltage of 1.9, two tungsten anodes in a litre bath containing 60 grams of NaOH, 200 grams of WO₃, 60 grams of dextrose and 7.5 cubic centimeters of HCl, maintained at a temperature of 65 degrees centigrade.

Excellent plating has also been obtained with the second above described bath at a temperature of 51 degrees centigrade with a current density of only 10 amperes per square foot of cathode plate. The bath temperature may be varied from 50 to 70 degrees centigrade, the current density being usually varied directly as the temperature. By properly regulating the current density the process may be made operative at ordinary room temperature. For rapid working, however, the higher degrees of temperature of the bath are advisable and may even exceed the upper limit given above.

So far as I have now been able to determine, the quantity of the acid (if used at all) must not materially exceed the proportions given in certain of the above stated examples, which are not sufficient to overcome the predominant alkalinity of the bath when the sodium hydroxide, or equivalent constituent is present. If hydrochloric acid exceeds 10 cubic centimeters per litre of the bath, the electro-deposition of metallic tungsten in the bath stops, and only a sub-oxide is deposited. Other acids such as sulphuric, may be employed but the best results are secured with an acid having a halogen radical, preferably hydrochloric, as stated. Hydrofluoric acid also gives good results.

If the cathode plate is mechanically polished or cleaned with acid, or both, before immersion a perfect mirror-like lustre results in the plated tungsten surface.

During the operation of the process hydrogen bubbles are liberated quite rapidly at the cathode and the tungsten anode (if one is used) is rapidly eaten away. A carbon anode could be substituted and the supply of tungsten for deposition obtained entirely from the tungsten oxide in the bath by adding proper quantities thereof from time to time, but it is simpler to replace the tungsten by decomposition of a tungsten anode, as this more nearly stabilizes the proportions of the bath constituents. If the tungsten anode goes into solution too rapidly, a carbon anode may be used in combination with it and the submerged area of the tungsten anode properly adjusted to insure the desired rate of corrosion thereof. A supplementary anode of lead may also be used, and the very small quantity of lead which then goes into solution seems to have a beneficial effect in cleansing the tungsten film first deposited on the cathode and thus facilitating a continuous plating action so as to build up a thicker coat of the plating. One rather peculiar phenomenon is that while the first complete film of tungsten is deposited in a few minutes, subsequent building-up of the plating advances rather slowly, unless the lead, or other cathode depolarizer is used. The proportion of material so used as a cathode depolarizer may be so small as to be practically not discoverable in the plated layer, or appear only as a barely discoverable trace therein. When a supplementary anode of lead, or other cathode depolarizing material, is thus used the same is slowly eaten away to form in the bath a solution of a salt of that material, and, obviously an equivalent result could be obtained by adding such a salt directly to the bath, thus dispensing with, or supplementing the action of the supplementary anode.
The sodium hydroxide or the hydrochloric acid need only occasional replacement in continuous operation and the dextrose, when present in excess, will last for a long time.

Other alkali metal salts may be substituted for the hydroxide. Ammonia compounds, however, have not so far proved satisfactory, although ammonium hydroxide can be used if very skillful manipulation is exercised to prevent its evaporation. Also lithium carbonate has been found to give excellent results. The reason why special care must be exercised to prevent the evaporation of any volatile alkaline compounds is, of course, that it is necessary to maintain substantial uniformity of alkalinity throughout the plating operation of any alkaline bath used.

Alkaline metal compounds other than the hydroxide may, however, be used, such as the carbonates.

Thus sodium carbonate (Na₂CO₃) may be substituted for sodium hydroxide in my process and when used has produced even better results than does the hydroxide in tungsten plating. In plating with aluminum, however, the hydroxide bath with dextrose has so far given the best results. In carrying out the process in aluminum plating I prefer to use 150 grams sodium alumi- nate (Na₃Al₂O₅·12H₂O), 75 grams of dextrose and 80 grams of sodium hydroxide (NaOH) per litre of bath solution and electrolyze at a temperature of about 80°C with current densities the same as in the case of the tungsten plating.

I have also carried out the above described process when using a carbon anode and substituting thorium oxide (ThO₂), the material used commercially in making gas burner mantles) and obtained a beautiful plating of pure metallic thorium on brass. In this modification of the general process the sodium hydroxide when used in the bath presumably combines with the thorium to form a thorium compound which is much more soluble than the original thorium oxide.

As an example of my process as success- fully applied in the thorium plating, I may prepare a bath containing, per litre, 40 grams of sodium hydroxide (NaOH) 21 grams of thorium oxide (ThO₂) in suspension, 60 grams of dextrose (C₆H₁₂O₆) and subject it to a current density of about 36 amperes per square foot of submerged cathode surface, at from 3 to 5 volts, said bath being maintained at a temperature of about 80 centigrade. If a trace of nickel hydrate (Ni(OH)₂) is added the thickness of plating obtainable is increased in the manner set forth with reference to the use of a supplementary anode of lead or other cathode depolarizer.

If the plating of pure thorium so produced is exposed to the atmosphere for any con- siderable period of time it changes into the white oxide of thorium, but this would not occur if the plated article were immediately placed in a vacuum, as if used in a radio tube, or if surrounded by an atmosphere of neutral or reducing gas.

I have also obtained a satisfactory plating of titanium by using a bath containing, per litre, 10 grams of titanium oxide (TiO₂) in suspension, 15 cubic centimeters of hydrofluoric acid (HF) chemically pure, or 30 cubic centimeters of the commercial 50% solution of such acid, 10 cubic centimeters of hydrochloric acid (HCl), and 0.5 gram of gelatine. This titanium bath I subject to a current density of about 1 ampere per square inch of submerged cathode area, at a voltage of from 4 to 6 volts, maintaining the bath at a temperature of about 80°C centigrade.

Plating of tungsten and similar metals can also be obtained from a bath having very finely divided metallic particles of the plating metal maintained in suspension in a di- lute acid bath, such as hereinbefore sug- gested. Thus by maintaining fine tungsten metal powder, such as was formerly used in making pressed lamp filaments, in suspen- sion in a dilute sulphuric acid bath (of about 1% strength) of either copper, cobalt or nickel sulphate and subjecting the bath to a current density of about 14/2 amperes per square inch of submerged cathode surface at a volt- age of from 3 to 5 volts, the bath being maintained at a temperature of about 60 to 70 degrees centigrade, a complete, adherent con- tinuous plating of metallic tungsten plus a little copper, cobalt or nickel is obtained. While the plating so produced does not have the absolutely smooth surface, and consequent original polish and mirror-like effect, of those produced by the preferred forms of the invention hereinbefore described, it is composed largely of tungsten and would be useful for industrial purposes where appearance is not important, as in apparatus where the object is to protect the plated surfaces from the corrosive action of hot gases.

In this, as in other modifications of my process, it is necessary to properly balance the negative exponent of the hydrogen-ion concentration of the solution represented by what is known as the pH number, all as explained in the co-pending application Ser. No. 362,854, filed by Frank L. Jones and myself May 13, 1929.

In operating the modifications of my proc- ess employing an alkaline bath other forms of fixed alkali salts than those previously mentioned may, of course, by substituted, such as, potassium hydrate (KOH), lithium hydrate (LiOH) or barium hydrate (Ba(OH)₂).

The commercial advantages of the invention are obvious, as the materials used are plentiful and comparatively cheap, the current consumption small and the manipulation involves merely standard electro-plating.
practice. Little or no artificial heat is required as compared with that employed in the operation of the fused bath processes, and cathode bases melting or disintegrating at low temperatures may be employed.

As this plated coating of tungsten is practically insoluble in all acids, various forms of containers such as tanks, crucibles and similar articles used in laboratories and in chemical plants can now be made of cheap metal bases, tungsten-plated, in place of the costly quartz, treacherous porcelain-lined apparatus, or heavy earthenware now used.

As the tungsten plating is absolutely resistant to atmospheric corrosion, highly polished lamp reflectors for automobile and other lamps made of it will never dim.

If the plating process can be carried far enough, high resistance conductors for electric heating apparatus can be made by heavily plating thin copper ribbons and then removing the copper by volatilization by heat, or by dissolving out with nitric acid. Tungsten filaments can then be similarly made by heavily plating a very fine copper wire to form a long rod, drawing this down and subsequently removing the copper by heat or acids.

Under similar conditions cutting edges to tools can be tungsten-plated and subsequently heat-treated, pen points can be tipped with tungsten in place of iridium, contacts for ignition systems, and targets for X-ray apparatus can be made by tungsten plating in place of the costly swaged structures of solid tungsten now required. Artistic bronze effects can be produced by even a light plating of tungsten on a cheaper metal base and subsequently heat-treating in proper packings.

Also, as the efficiency of audionics, or radio tubes, and other vacuum tubes, is now known to be dependent on the thorium present in the standard tungsten drawn wire filament, it is obvious that the useful life and efficiency of such filaments may be immensely increased by plating them with thorium or other radio active metal, or by plating tungsten on a thorium base, or by building them up in alternately plated layers of tungsten and of thorium. Heretofore it has been proposed to use thorium filaments in radio apparatus but the melting point of pure thorium is so low that such filaments will not stand up at operating temperatures. Evidently this difficulty can be overcome by stiffening the thorium body with a core or with an envelope of tungsten produced by my improved plating process herein described.

These and other specific embodiments of the broad invention here described and claimed will be specifically described and claimed in applications to be subsequently filed.

The plating produced by the process herein described, when performed on a smooth or polished cathode surface, has the same smoothness as said cathode surface had before being subjected to the plating operation. Furthermore, the plated layer produced by my process is amorphous in structure, while all other electrochemically deposited metallic bodies now or heretofore produced are and have been, so far as known to me, crystalline in structure. Why the process hereinbefore described produces an amorphous deposit instead of one which is crystalline as in previous electrochemical plating processes, I have not as yet been able to determine, but the importance of this amorphous structure of the plated layer is obvious. Such layer of amorphous material is tougher and less liable to crack and flake off than a crystalline layer would be. Also there is an absence of the intercrystalline spaces occurring in any crystalline structure which sometimes form pin holes through any such plated layer of crystalline character and so admit acids and water and vapors for destructive action on the material beneath which was intended to be protected by the plated layer.

As I employ an aqueous bath it is obvious that my process can be used successfully on any "work" as a cathode which will not be deformed or otherwise injuriously affected by exposure to the temperature of boiling water.

Having described my invention, I claim:

1. An electroplating bath comprising an aqueous solution formed by adding tungstic acid and an alkali metal salt to water in proportions producing a hydrogen-ion concentration in the resultant bath represented by a pH value of about 12.

2. An electroplating bath of predetermined alkalinity formed by preparing aqueous solutions containing tungstic acid, an alkali metal salt of tungstic acid and a soluble carbohydrate.

3. An electroplating bath comprising an aqueous solution of predetermined alkalinity formed by introducing into water tungstic acid, an alkali metal hydroxide and dextrose, said bath being heated to a point above room temperature but below boiling point.

4. An electroplating bath comprising an aqueous solution of a tungstate formed from a mixture of tungstic acid and an alkali metal hydroxide, such as sodium hydroxide, in the proportions of about 31 parts by weight of the tungstic acid to about 79 parts by weight of the hydroxide per litre of the solution and to which has been added an excess of a carbohydrate soluble in water, such as dextrose.

5. An electroplating bath comprising an aqueous solution of an alkali tungstate of predetermined alkalinity equivalent to a degree of hydrogen-ion concentration approximating that represented by the pH number 12.

6. A process of electroplating with metals such as tungsten, thorium, titanium and aluminum heretofore found difficult or im-
possible to reduce in aqueous baths, which comprises forming an aqueous bath of predetermined alkalinity by adding to water an oxide of the metal selected and an alkali metal salt of such oxide and heating said bath to a temperature of at least about 55 degrees centigrade but below boiling point while subjecting it to electrolysis.

7. A process of electrophating with metals such as tungsten, thorium, titanium and aluminum heretofore found difficult or impossible to reduce in aqueous baths, which comprises forming an aqueous bath of predetermined alkalinity by adding to water an oxide of the metal selected and an alkali metal salt of such oxide and heating said bath to a temperature of at least about 55 degrees centigrade but below boiling point while subjecting it to electrolysis by an electric current having a density of about 200 amperes per square foot of submerged cathode area.

8. A process of electrophating with tungsten comprising forming an aqueous bath having a degree of alkalinity approximating that represented by the pH value 12 by adding tungstic acid, an alkali metal hydroxide, and a water-soluble carbohydrate, to water, and heating said bath to a temperature of at least about 55 degrees centigrade but below boiling point while subjecting it to electrolysis.

9. A process of electrophating with tungsten which comprises forming an aqueous bath having a degree of alkalinity approximating that represented by the pH value 12 by adding tungstic acid, an alkali metal hydroxide, and a water-soluble carbohydrate, to water, and heating said bath to a temperature of at least about 55 degrees centigrade but below boiling point while subjecting it to electrolysis by an electric current of sufficient amperage to produce a fairly copious evolution of hydrogen bubbles on the surface of the cathode.

10. A process of electrophating with tungsten which comprises adding to an aqueous bath about 30 grams of tungstic acid and about 75 grams of an alkali metal hydroxide per litre of bath volume, together with a carbobrate susceptible of partial decomposition by said hydroxide, and subjecting said bath to electrolysis by an electric current sufficient to produce a fairly copious evolution of hydrogen bubbles on the surface of the cathode.

11. The method of preparing pure metallic tungsten comprising forming an aqueous solution of a salt thereof and decomposing the same by electricity to deposit tungsten therefrom.

12. The method of electrophating with tungsten comprising dissolving a compound thereof in an aqueous bath and passing a current between an anode and a cathode in the solution so formed while it is heated above room temperature but below boiling point; whereby tungsten is plated upon the cathode.

13. The method of forming tungsten metal comprising preparing a solution of a tungsten compound in water at a temperature approximating the boiling point of said solution and decomposing said compound by passing electricity between an anode and a cathode therein; whereby a coating of substantially pure tungsten is deposited on the cathode.

14. The method of electrophating with metals heretofore found difficultly reducible in aqueous baths, such as tungsten, thorium, titanium and aluminum, which comprises mixing an aqueous solution of an oxide of the selected metal with an alkali metal salt of such oxide also soluble in water and adding a carbohydrate susceptible of partial decomposition by said alkali metal solution to reduce the alkalinity of the completed bath, and subjecting said bath to an electric current of sufficient amperage to produce a fairly copious evolution of hydrogen bubbles on the surface of the bath at the cathode.

15. A process for producing an adherent plated layer of tungsten having a lustrous and smooth surface without subsequent mechanical polishing, which comprises subjecting a metallic cathode having a lustrous, polished surface to electrolytic action in an aqueous solution of an alkali tungstate of predetermined alkalinity.

16. A process for producing substantially pure plating of a suitable cathode in an electrically-conductive aqueous bath of controlled, uniform alkalinity containing a metallic element of the class heretofore found difficult to reduce in such bath such as tungsten, thorium, titanium and aluminum and a minute quantity of a metal capable of acting as a cathode depolarizer, which process comprises subjecting said bath to the passage of current adjusted to produce a fairly copious evolution of hydrogen bubbles at the surface thereof around the cathode, whereby there is deposited on said cathode a plated layer of the first mentioned metal of any desired thickness and containing only a barely discoverable trace of said depolarizing metal.

17. A process for producing substantially pure plating on a suitable cathode in an electrically-conductive aqueous bath of controlled, uniform alkalinity containing a metallic element of the class heretofore found difficult to reduce in such bath such as tungsten, thorium, titanium and aluminum and a minute quantity of a metal capable of acting as a cathode depolarizer, which process comprises subjecting said bath to the passage of current adjusted to produce a fairly copious evolution of hydrogen bubbles at the surface thereof around the cathode, and heating said bath to about a boiling temperature, whereby
there is deposited on said cathode a plated layer of the first mentioned metal of any desired thickness and containing only a barely discoverable trace of said depolarizing metal.

18. A process for producing substantially pure tungsten plating on a suitable cathode in an aqueous bath of controlled, uniform alkalinity containing tungsten, a minute quantity of a salt of a metal capable of acting as a cathode depolarizer, such as lead, and an alkali metal salt, which process comprises subjecting said bath to the passage of current adjusted to produce a fairly copious evolution of hydrogen bubbles at the surface thereof around the cathode, whereby there is deposited on said cathode a plated layer of substantially pure tungsten of any desired thickness.

19. A process for producing substantially pure tungsten plating on a suitable cathode in an aqueous bath of controlled, uniform alkalinity containing a minute quantity of a salt of a metal capable of acting as a cathode depolarizer, such as lead, an alkali metal hydroxide, a tungsten anode and a minor proportion of a constituent having a halogen radical to counteract polarization at said anode, which process comprises subjecting said bath to the passage of a current adjusted to produce a fairly copious evolution of hydrogen bubbles at the surface thereof around the cathode and heating said bath to about boiling temperature, whereby there is deposited on said cathode a plated layer of substantially pure tungsten of any desired thickness.

20. The product of the herein described process, being an adherent plating of substantially pure metallic tungsten amorphous in structure.

COLIN G. FINK.