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Standard Guide for Electrolytic Polishing of Metallographic Specimens[1]

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1. Scope

1.1 This guide deals with electrolytic polishing as a means of preparation of specimens for metallographic purposes. Procedures are described for polishing a variety of metals.

NOTE 1—References **(1-133)**[2] on electrolytic polishing will provide the reader with specific information beyond the scope of this guide.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific safety precautions are described in Section 5 and 6.3.1.

2. Referenced Documents

2.1 *ASTM Standards:*

E 3 Methods of Preparation of Metallographic Specimens[3]

E 7 Terminology Relating to Metallography[3]

E 407 Test Methods for Microetching Metals and Alloys[3]

3. Terminology

3.1 *Definitions*—All terms used in this guide are either defined in Terminology E 7 or are discussed in 3.2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *electrolytic polish (electropolish)*—A method of polishing metals and alloys in which material is removed from the surface by making the metal the anode in an electrolytic bath.

4. Significance and Use

4.1 *Advantages of Electrolytic Polishing*:

4.1.1 For some metals, a high quality surface finish can be produced that is equivalent to, or better than, that which can be obtained by mechanical methods.

4.1.2 Once procedures have been established, satisfactory results can be obtained rapidly with reproducibility.

4.1.3 There can be a marked saving of time if many specimens of the same material are polished sequentially.

4.1.4 Electropolishing a selected area on the surface of a relatively large metal part can be accomplished nondestructively, that is, without the need for sectioning to remove a piece.

4.1.5 Soft, single-phase metals, which may be difficult to polish by mechanical methods, may be successfully electropolished.

4.1.6 The true microstructure of a specimen can be obtained because artifacts (such as disturbed metal, scratches, and mechanical twins), produced on the surface even by careful grinding and mechanical polishing operations, can be removed. These features are important in low-load hardness testing, X-ray diffraction studies, and in electron microscopy, where higher resolution puts a premium on undistorted metal surfaces.

4.1.7 After electropolishing is completed, etching can often be accomplished by reducing the voltage (generally to about one-tenth that required for polishing) for a short time before it is turned off.

NOTE 2—Not all electropolishing solutions produce good etching results.

4.2 *Disadvantages of Electrolytic Polishing*:

4.2.1 Many of the chemical mixtures used in electropolishing are poisonous or dangerous if not properly handled (see Section 5). These hazards are similar to those involved in the mixing and handling of etchants, see Test Methods E 407.

4.2.2 In multi-phase alloys, the polishing rate of each phase may be different. The result may be a non-planar surface.

4.2.3 Electropolished surfaces may be slightly undulated rather than perfectly planar and, therefore, may not be suitable for examination at all magnifications.

4.2.4 The rate of polishing in areas adjacent to various inhomogeneities, such as nonmetallic inclusions and voids, is usually greater than that in the surrounding matrix and tends to exaggerate the size of the inclusions and voids.

4.2.5 Dimples, pits, and waviness limit applications involving surface phenomena, coatings, interfaces, and cracks. Edges tend to be attacked preferentially, resulting in edge rounding.

4.2.6 Artifacts may be produced by electropolishing.

4.2.7 Specimen mounting materials may react with the electrolyte.

[1] This guide is under the jurisdiction of ASTM Committee E-4 on Metallography and is the direct responsibility of Subcommittee E04.01 on Sampling, Specimen Preparation, and Photography.

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[2] The **boldface** numbers in parentheses refer to the references at the end of this standard.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

4.2.8 The electropolished surfaces of certain materials may be passive and difficult to etch.

4.2.9 Metal removal rates by electropolishing are usually quite low, typically about 1 μm/min, and all of the prior induced damage from cutting and grinding may not be removed if preparation is stopped after a 600-grit SiC grind and electropolishing times are short.

4.2.10 A large number of electrolytes may be needed to polish the variety of metals encountered by a given laboratory. Considerable time may be required to develop a procedure for a new alloy.

5. General Safety Precautions

5.1 Before using or mixing any chemicals, all product labels and pertinent Material Safety Data Sheets (MSDS) should be read and understood concerning all of the hazards and safety precautions to be observed. Users should be aware of the type of hazards involved in the use of all chemicals used, including those hazards that are immediate, long-term, visible, invisible, and with or without odors.

5.1.1 Consult the product labels and MSDS for recommendations concerning proper protective clothing.

5.1.2 All chemicals are potentially dangerous. All persons using any electrolyte should be thoroughly familiar with all of the chemicals involved and the proper procedure for handling, mixing, and disposing of each chemical, as well as any combinations of those chemicals.

5.1.3 Table 2 includes specific safety precautions for the mixing or use of some electrolytes. The user should take care to observe each of these specific precautions.

TABLE 2 Electrolytes for Electropolishing

Class	Use	Formula		Cell Voltage	Time	Remarks
Group I (Electrolytes Composed of Perchloric Acid and Alcohol With or Without Organic Additions)						
I-1	Al and Al alloys with less than 2 percent Si	ethanol (95 %)	800 mL	30 to 80	15 to 60 s	
		distilled water	140 mL			
		perchloric acid (60 %)	60 mL			
	steels—carbon, alloy, stainless			35 to 65	15 to 60 s	
	Pb, Pb-Sn, Pb-Sn-Cd, Pb-Sn-Sb			12 to 35	15 to 60 s	
	Zn, Zn-Sn-Fe, Zn-Al-Cu			20 to 60	...	
	Mg and high Mg alloys			...	...	nickel cathode
I-2	stainless steel and aluminum	ethanol (95 %)	800 mL	35 to 80	15 to 60 s	
		perchloric acid (60 %)	200 mL			
I-3	stainless steel	ethanol (95 %)	940 mL	30 to 45	15 to 60 s	
		perchloric acid (65 %)	60 mL			
I-4	steel, cast iron, Al, Al alloys, Ni, Sn, Ag, Be, Ti, Zr, U, heat-resisting alloys	ethanol (95 %)	700 mL	30 to 65	15 to 60 s	one of the best formulas for universal use
		2-butoxy ethanol	100 mL			
		perchloric acid (30 %)	200 mL			
I-5	steels—stainless, alloy, high-speed; Fe, Al, Zr, Pb	ethanol (95 %)	700 mL	15 to 50	15 to 60 s	universal electrolyte comparable to I-4
		glycerin	100 mL			
		perchloric acid (30 %)	200 mL			

TABLE 1 Electropolishing Procedural Problems and Corrections

Trouble	Possible Cause	Suggested Correction
Center of specimen deeply etched	no polishing film at center of specimen	(*1*) increase voltage (*2*) decrease agitation (*3*) use more viscous electrolyte
Pitting or etching at edges of specimen	too viscous or thick film	(*1*) decrease voltage (*2*) increase agitation (*3*) use less viscous electrolyte
Sludge settling on surface	insoluble anode product	(*1*) try new electrolyte (*2*) increase temperature (*3*) increase voltage
Roughness or matte surface	insufficient or no polishing film	(*1*) increase voltage (*2*) use more viscous electrolyte
Waviness or streaks on polished surface	(*1*) insufficient time (*2*) incorrect agitation (*3*) inadequate preparation (*4*) too much time	(*1*) increase or decrease agitation (*2*) better preparation (*3*) increase voltage and decrease time
Stains on polished surface	attack after polishing current is off	(*1*) remove specimen while current is still on (*2*) try less corrosive electrolyte
Unpolished spots (bullseyes)	gas bubbles	(*1*) increase agitation (*2*) decrease voltage
Phases in relief	insufficient polishing film	(*1*) increase voltage (*2*) better preparation (*3*) decrease time
Pitting	(*1*) too long polishing (*2*) too high voltage	(*1*) better preparation (*2*) decrease voltage (*3*) decrease time (*4*) try different electrolyte

TABLE 2 *Continued*

Class	Use	Formula		Cell Voltage	Time	Remarks
I-6	Al, Al-Si alloys	ethanol (95 %)	760 mL	35 to 60	15 to 60 s	particularly good with Al-Si alloys
		diethyl ether	190 mL			
		perchloric acid (30 %)	50 mL			
I-7	Mo, Ti, Zr, U-Zr alloy	methanol (absolute)	600 mL	60 to 150	5 to 30 s	
		2-butoxy ethanol	370 mL			
		perchloric acid (60 %)	30 mL			
I-8	Al-Si alloys	methanol (absolute)	840 mL	50 to 100	5 to 60 s	
		glycerin	125 mL			
		perchloric acid (65 %)	35 mL			
I-9	vanadium	methanol (absolute)	590 mL	30	3 s	three-second cycles repeated at
		2-butoxy ethanol	350 mL			least seven times to prevent heating
		perchloric acid (65 %)	60 mL			
	germanium			25 to 35	30 to 60 s	
	titanium			58 to 66	45 s	polish only
	zirconium			70 to 75	15 s	polish and etch simultaneously
I-10	aluminum	methanol (absolute)	950 mL	30 to 60	15 to 60 s	
		nitric acid	15 mL			
		perchloric acid (60 %)	50 mL			
I-11	steels—carbon, alloy, stainless	methanol (absolute)	600 mL	30–40	5–60 s	good all purpose electropolish
	Ti, high-temperature alloys, Pb,	butylcellosolve	360 mL			
	Mo	perchloric acid	60 mL			
I-12	Al and Al alloys	ethanol (95 %)	1000 mL	10	2 min	not good for Al-Cu and Al-Si alloys.
		perchloric acid	200 mL			Black film forms. Peel off after 1–1.5 min and polish 1 min more.
I-13	steel, Al, Ni, Sn, Ti, Be	ethanol (95 %)	700 mL	20	20 s	Mix ethanol and water, add
	stainless steel	butylcellosolve	100 mL			perchloric acid carefully. Then, add
	Al_3Ni	water	137 mL			butylcellosolve before use.
		perchloric acid	62 mL			
I-14	Ni, Ag or Cu alloys	ethanol (95 %)	700 mL	70–80	15 s	
	Cd	butylcellosolve	100 mL			
		perchloric acid	200 mL			
I-15	Mo and Mo alloys	methanol (absolute)	600 mL		20 s	Mix methanol and water, add
		water	13 mL			perchloric acid carefully. Add
		butylcellosolve	360 mL			butylcellosolve before use.
		perchloric acid	47 mL			
Group II (Electrolytes Composed of Perchloric Acid and Glacial Acetic Acid in Varying Proportions)						
II-1	Cr, Ti, Zr, U	acetic acid (glacial)	940 mL	20 to 60	1 to 5 min	good general-purpose electrolyte
	Fe, steel—carbon, alloy, stainless	perchloric acid (60 %)	60 mL			
II-2	Zr, Ti, U, steel—carbon and alloy	acetic acid (glacial)	900 mL	12 to 70	0.5 to 2 min	
		perchloric acid (60 %)	100 mL			
II-3	U, Zr, Ti, Al, steel—carbon and	acetic acid (glacial)	800 mL	40 to 100	1 to 15 min	
	alloy	perchloric acid (60 %)	200 mL			
II-4	Ni, Pb, Pb-Sb alloys	acetic acid (glacial)	700 mL	40 to 100	1 to 5 min	
		perchloric acid (60 %)	300 mL			
II-5	3 percent Si-Fe	acetic acid (glacial)	650 mL	...	5 min	0.06 A/cm^2
		perchloric acid (60 %)	350 mL			
II-6	Cr	acetic acid (glacial)	1000 mL	30–50	2–3 min	can lower voltage to 25 V by adding
		perchloric acid	5 mL			5–15 % water.
II-7	Hf, steel—carbon and alloy	acetic acid (glacial)	1000 mL	...	...	Used to polish Hf wires.
		perchloric acid	50 mL			

TABLE 2 *Continued*

Class	Use	Formula		Cell Voltage	Time	Remarks
Group III (Electrolytes Composed of Phosphoric Acid in Water or Organic Solvent)						
III-1	cobalt	phosphoric acid (85 %)	1000 mL	1.2	3 to 5 min	
III-2	pure copper	distilled water phosphoric acid (85 %)	175 mL 825 mL	1.0 to 1.6	10 to 40 min	copper cathode
III-3	stainless, brass, Cu and Cu alloys except Sn bronze	water phosphoric acid (85 %)	300 mL 700 mL	1.5 to 1.8	5 to 15 min	copper cathode
III-4	alpha or alpha plus beta brass, Cu-Fe, Cu-Co, Co, Cd	water phosphoric acid (85 %)	600 mL 400 mL	1 to 2	1 to 15 min	copper or stainless steel cathode
III-5	Cu, Cu-Zn	water pyrophosphoric acid	1000 mL 580 g	1 to 2	10 min	copper cathode
III-6	steel	diethylene glycol monoethyl ether phosphoric acid (85 %)	500 mL 500 mL	5 to 20	5 to 15 min	120°F
III-7	Al, Ag, Mg	water ethanol (95 %) phosphoric acid (85 %)	200 mL 380 mL 400 mL	25 to 30	4 to 6 min	aluminum cathode, 100 to 110°F
III-8	uranium	ethanol (absolute) glycerin (cp) phosphoric acid (85 %)	300 mL 300 mL 300 mL	...	...	
III-9	Mn, Mn-Cu alloys	ethanol (95 %) glycerin phosphoric acid (85 %)	500 mL 250 mL 250 mL	18	...	
III-10	Cu and Cu-base alloys	distilled water ethanol (95 %) phosphoric acid (85 %)	500 mL 250 mL 250 mL	...	1 to 5 min	
III-11	stainless steel	ethanol (absolute), to pyrophosphoric acid	1 L 400 g	...	10 min	good for all austenitic heat resistant alloys, 100°F plus
III-12	Mg-Zn	ethanol (95 %) phosphoric acid (85 %)	625 mL 375 mL	1.5 to 2.5	3 to 30 min	
III-13	uranium	ethanol (95 %) ethylene glycol phosphoric acid (85 %)	445 mL 275 mL 275 mL	18 to 20	5 to 15 min	0.03 A/cm^2
III-14	Al-Mg alloys	water ethanol (95 %) phosphoric acid (85 %)	250 mL 380 mL 400 mL	50–60	2 min	
III-15	Cu-Pb alloys	ethanol (95 %) phosphoric acid (85 %)	620 mL 380 mL			good up to 30 % Pb
III-16	Neptunium	ethanol (95 %) glycerol phosphoric acid (85 %)	400 mL 400 mL 800 mL			after 600-grit SiC, use 6-µm diamond on nylon before electropolishing.
Group IV (Electrolytes Composed of Sulfuric Acid in Water or Organic Solvent)						
IV-1	stainless steel	water sulfuric acid	250 mL 750 mL	1.5 to 6	1 to 2 min	
IV-2	stainless steel, Fe, Ni	water sulfuric acid	400 mL 600 mL	1.5 to 6	2 to 6 min	
IV-3	stainless steel, Fe, Ni, Mo	water sulfuric acid	750 mL 250 mL	1.5 to 6	2 to 10 min Mo— 0.3 to 1 min	particularly good for sintered Mo—32 to 80°F
IV-4	molybdenum	water sulfuric acid	900 mL 100 mL	1.5 to 6	0.3 to 2 min	particularly good for sintered Mo—32 to 80°F
IV-5	stainless steel	water glycerin sulfuric acid	70 mL 200 mL 720 mL	1.5 to 6	0.5 to 5 min	
IV-6	stainless steel, aluminum	water glycerin sulfuric acid	220 mL 200 mL 580 mL	1.5 to 12	1 to 20 min	
IV-7	molybdenum	methanol (absolute) sulfuric acid	875 mL 125 mL	6 to 18	0.5 to 1.5 min	32 to 80°F
IV-8	Ni-base superalloys	methanol (absolute) sulfuric acid	800 mL 200 mL	30	20 s	for alloy 625
Group V (Electrolytes Composed of Chromic Acid in Water)						
V-1	stainless steel	water chromic acid	830 mL 620 g	1.5 to 9	2 to 10 min	
V-2	Zn, brass	water chromic acid	830 mL 170 g	1.5 to 12	10 to 60 s	

TABLE 2 *Continued*

Class	Use	Formula		Cell Voltage	Time	Remarks
		Group VI (Mixed Acids or Salts in Water or Organic Solvent)				
VI-1	stainless steel	phosphoric acid (85 %)	600 mL	...	...	
		sulfuric acid	400 mL			
VI-2	stainless steel	water	150 mL	...	2 min	0.3 A/cm^2
		phosphoric acid (85 %)	300 mL			
		sulfuric acid	550 mL			
VI-3	stainless and alloy steel	water	240 mL	...	2 to 10 min	0.1 to 0.2 A/cm^2
		phosphoric acid (85 %)	420 mL			
		sulfuric acid	340 mL			
VI-4	stainless steel	water	330 mL	...	1 min	0.05 A/cm^2
		phosphoric acid (85 %)	550 mL			
		sulfuric acid	120 mL			
VI-5	bronze (to 9 % Sn)	water	450 mL	...	1 to 5 min	0.1 A/cm^2
		phosphoric acid (85 %)	390 mL			
		sulfuric acid	160 mL			
VI-6	bronze (to 6 % Sn)	water	330 mL	...	1 to 5 min	0.1 A/cm^2
		phosphoric acid (85 %)	580 mL			
		sulfuric acid	90 mL			
VI-7	steel	water	140 mL	...	1 to 5 min	1 to 5 A/cm^2, 100°F plus
		glycerin	100 mL			
		phosphoric acid (85 %)	430 mL			
		sulfuric acid	330 mL			
VI-8	stainless steel	water	200 mL	...	5 min	1 A/cm^2, 80 to 120°F
		glycerin	590 mL			
		phosphoric acid (85 %)	100 mL			
		sulfuric acid	110 mL			
VI-9	stainless steel	water	260 mL	...	30 min	0.6 A/cm^2, 80 to 120°F
		chromic acid	175 g			
		phosphoric acid (85 %)	175 mL			
		sulfuric acid	580 mL			
VI-10	stainless steel	water	175 mL	...	60 min	0.5 A/cm^2, 80 to 120°F
		chromic acid	105 g			
		phosphoric acid (85 %)	460 mL			
		sulfuric acid	390 mL			
VI-11	stainless and alloy steel	water	240 mL	...	5 to 60 min	0.5 to A/cm^2, 100 to 130°F
		chromic acid	80 g			
		phosphoric acid (85 %)	650 mL			
		sulfuric acid	130 mL			
VI-12	tantalum	hydrofluoric acid	100 mL	...	9 min	graphite cathode, 0.1 A/cm^2, 90 to 100°F
		sulfuric acid	900 mL			
VI-13	stainless steel	water	210 mL	...	5 min	0.5 A/cm^2, 70 to 120°F
		hydrofluoric acid	180 mL			
		sulfuric acid	610 mL			
VI-14	zinc	water	800 mL	...	...	0.002 A/cm^2, 70 to 100°F
		chromic acid	100 g			
		sulfuric acid	46 mL			
		sodium dichromate	310 g			
		acetic acid (glacial)	96 mL			
VI-15	stainless steel	hydrogen peroxide (30 %) **(Caution)**	260 mL	...	5 min	0.5 A/cm^2**(Caution) Dangerous**
		hydrofluoric acid	240 mL			
		sulfuric acid	500 mL			
VI-16	stainless steel	water	520 mL	...	½ to 4 min	0.08 to 0.3 A/cm^2
		hydrofluoric acid	80 mL			
		sulfuric acid	400 mL			
VI-17	stainless steel	water	600 mL	...	...	
		chromic acid	180 g			
		nitric acid	60 mL			
		hydrochloric acid	3 mL			
		sulfuric acid	240 mL			
VI-18	bismuth	glycerin	750 mL	12	1 to 5 min	0.5 ± A/cm^2**(Caution)** This mixture will decompose vigorously after a short time. Do not try to keep.
		acetic acid (glacial)	125 mL			
		nitric acid	125 mL			
VI-19	magnesium	ethylene-glycol-monoethyl ether	900 mL	50 to 60	10 to 30 s	Bath should be stirred. Cool cracked ice below 35°F
		hydrochloric acid	100 mL			
VI-20	molybdenum, sintered and cast	methanol (absolute)	685 mL	19 to 35	20 to 35 s	Mix slowly. Heat is developed. Avoid contamination with water. Below 35°F.
		hydrochloric acid	225 mL			
		sulfuric acid	90 mL			

TABLE 2 *Continued*

Class	Use	Formula		Cell Voltage	Time	Remarks
		Group VI (Mixed Acids or Salts in Water or Organic Solvent)—*Continued*				
VI-21	titanium	ethanol (95 %)	900 mL	30 to 60	1 to 6 min	**(Caution)** Anhydrous aluminum chloride is extremely dangerous to handle.
		n-butyl alcohol	100 mL			
		aluminum chloride (anhydrous) (add very slowly) **(Caution)**	60 g			
		zinc chloride (anhydrous)	250 g			
VI-22	uranium	acetic acid (glacial)	750 mL	80	5 to 30 min	The chromic acid is dissolved in the water before adding to the acetic acid. Below 35°F.
		distilled water	210 mL			
		chromic acid	180 g			
VI-23	pure zinc	ethanol (95 %)	720 mL	25 to 40	0.5 to 3 min	**(Caution)** Anhydrous aluminum chloride is extremely dangerous to handle. Below 60°F.
		aluminum chloride (anhydrous) **(Caution)**	50 g			
		zinc chloride (anhydrous)	225 g			
		distilled water	160 mL			
		n-butyl alcohol	80 mL			
VI-24	zirconium. Polish and etch simultaneously	glycerin **(Caution)**	870 mL	9 to 12	1 to 10 min	**(Caution)** will decompose on standing, dangerous if kept too long
		hydrofluoric acid	43 mL			
		nitric acid	87 mL			
VI-25	bismuth	saturated solution KI in distilled water	980 mL	7	30 s	polish 30 s but allow to remain in electrolyte until brown film is dissolved
		hydrochloric acid	20 mL			
VI-26	Sb	methanol (absolute)	300 mL	6–10	2–4 min	pure Sb. Use Pt cathode and anode lead wires. Agitate bath. Do not touch polished surface with cotton.
		sulfuric acid	50 mL			
		hydrochloric acid	30 mL			
VI-27	Sb	ethanol (95 %)	30 mL			good for polarized light work
		glycerol	30 mL			
		phosphoric acid	100 mL			
		sulfuric acid	30 mL			
VI-28	Bi	water	200 mL			good for polarized light work
		phosphoric acid	100 mL			
		sulfuric acid	200 mL			
VI-29	Cr	water	210 mL	18		stir bath or specimen
		phosphoric acid	640 mL			
		sulfuric acid	150 mL			
VI-30	Ge	methanol (absolute)	1000 mL			
		hydrochloric acid	10 mL			
VI-31	Nb	water	300 mL	40		polish to α-alumina before electropolishing
		sulfuric acid	100 mL			
		hydrofluoric acid	100 mL			
VI-32	Nb	methanol (absolute)	940 mL	50–60	10 s	
		sulfuric acid	50 mL			
		hydrofluoric acid	15 mL			
VI-33	Ni-base superalloy	methanol (absolute)	170 mL	30	20 s	for Waspaloy and IN-100 mod. Etch at 5 V for 4 s.
		hydrochloric acid	30 mL			
		Group VII (Alkaline Electrolytes)				
VII-1	gold	water to	1000 mL	7.5	2 to 4 min	graphite cathode
		potassium cyanide	80 g			
		potassium carbonate	40 g			
		gold chloride	50 g			
VII-2	silver	water to	1000 mL	2.5	To 1 min	graphite cathode
		sodium cyanide	100 g			
		potassium ferrocyanide	100 g			
VII-3	silver	water to	1000 mL	...	To 9 min	graphite cathode, 0.003 to 0.009 A/cm^2
		potassium cyanide	400 g			
		silver cyanide	280 g			
		potassium dichromate	280 g			
VII-4	tungsten	water to	1000 mL	...	10 min	graphite cathode, 0.09 A/cm^2, 100 to 120 F
		trisodium phosphate	160 g			
VII-5	tungsten, lead	water to	1000 mL	...	8 to 10 min	graphite cathode, 0.03 to 0.06 A/cm^2
		sodium hydroxide	100 g			
VII-6	zinc, tin	water to	1000 mL	2 to 6	15 min	copper cathode, 0.1 to 0.2 A/cm^2
		potassium hydroxide	200 g			
VII-7	W	water	1000 mL		5 min	
		sodium hydroxide	20 g			
		Group VIII (Mixture of Methyl Alcohol and Nitric Acid)				
VIII-1	Ni, Cu, Zn, Monel, brass, Ni-chrome, stainless steel	methanol (absolute)	660 mL	40 to 70	10 to 60 s	very useful but dangerous
		nitric acid	330 mL			