Emulsion Formulary

E1[1]

E1 is a very simple and easy to make emulsion, requiring only the basics in terms of supplies, techniques and equipment. The emulsion is generally fine grain with an exposure index between 1 - 5, though this will depend on your choice of gelatin, among other things...

Technical Data	
Type	Single Jet, Bromide, Neutral
Approx. Shelf Life	3.00 months
Coating Capacity	+/- 25.00 ft^2
pH	--
Solution A	
Distilled Water	63.0 ml
Potassium Bromide [KBr]	8.0 g
Active Gelatin	10.0g
Solution B	
Distilled Water	63.0 ml
Silver Nitrate [$AgNO_3$]	10.0 g

1. PREPARATION OF STOCK SOLUTIONS. **Solution A** Add the potassium bromide to the distilled water and dissolve completely. Then, under constant agitation, slowly add the gelatin to the solution. Allow the gelatin to swell (approx. 20 minutes) and then slowly raise the temperature to 50 C. **Solution B** Dissolve the silver nitrate in the water and then slowly raise to 45 degree C
2. EMULSIFICATION. Emulsification should occur under a safelight (Kodak 1 or equivalent) or in complete darkness. Each solutions respective temperature should be maintained across the duration of emulsification. Begin by bring solution A to a rapid agitation followed by the addition of solution B across 10 minutes.
3. RIPENING. No ripening specified.
4. WASHING. No washing specified.
5. SENSITIZATION. No additional sensitization specified.
6. FINALS. Finals can be added at ones own discretion.

[1] Taken from Silver Gelatin: A User's Guide to Liquid Photographic Emulsions (Reed, Martin; Jones, Sarah - 2001) with modifications by Kevin Rice

E2[2]

E2 is another very simple and easy to make emulsion, requiring only the basics in terms of supplies, techniques and equipment. The emulsion is generally fine grain with an exposure index between 1 - 5, though this will depend on your choice of gelatin, among other things...

Technical Data	
Type	Single Jet, Chloride, Neutral
Approx. Shelf Life	3.00 months
Coating Capacity	+/- 25.00 ft^2
pH	--
Solution A	
Distilled Water	500.00 ml
Sodium Chloride [NaCl]	12.0 g
Active Gelatin	90.0g
Solution B	
Distilled Water	100.0 ml
Silver Nitrate [$AgNO_3$]	25.0 g

1. PREPARATION OF STOCK SOLUTIONS. **Solution A** Add the sodium chloride to the distilled water and dissolve completely. Then, under constant agitation, slowly add the gelatin to the solution. Allow the gelatin to swell (approx. 20 minutes) and then slowly raise the temperature to 50 degree C. **Solution B** Dissolve the silver nitrate in the water and then slowly raise to 50 degree C
2. EMULSIFICATION. Emulsification should occur under a safelight (Kodak 1 or equivalent) or in complete darkness. Each solutions respective temperature should be maintained across the duration of emulsification. Begin by bring solution A to a rapid agitation followed by the addition of solution B across 10 minutes.
3. RIPENING. Ripen the emulsion for 50 minutes at a temperature of 50 degree C.
4. WASHING. No washing specified.
5. SENSITIZATION. No additional sensitization specified.
6. FINALS. Finals can be added at ones own discretion.

[2] Taken from Silver Gelatin: A User's Guide to Liquid Photographic Emulsions (Reed, Martin; Jones, Sarah - 2001) with modifications by Kevin Rice

Kodak D-19[3]

Designed as a continuous-tone developer for scientific and technical work, D-19 is a high energy (i.e. high contrast) developer well suited for black and white reversal processes, among others. D-19 has good keeping properties and a high capacity as well.

Technical Data	
Type	Developer (MQ based, High Energy)
Approx. Shelf Life	3.00 months
Capacity	+/- 30.00 ft^2 per. 1,000.00 ml
pH	11.0
Stock Solution	
Water @ 52.0 C	750.0 ml
Metol [$C_7H_9NO \cdot 1/2H_2SO_4$]	2.0 g
Sodium Sulfite, Anhydrous [Na_2SO_3]	90.0 g
Hydroquinone [$C_6H_4(OH)_2$]	8.0 g
Sodium Carbonate (Anhydrous) [Na_2CO_3]	45.0 g
Potassium Bromide [KBr]	5.0 g
Water to make...	1,000.0 ml

1. MIXOLOGY.
   a. Measure out each constituent separately before proceeding.
   b. Bring water to temperature and dissolve a pinch (approx. 5.0 g per liter) of the sodium sulfite to the solution.
   c. While agitating the solution, dissolve each constituent in the order that they appear in the table above, making sure that each one is dissolved in it's entirely before the next addition.
2. STORAGE. Store the final stock solution in an airtight container. Protect from light when possible.
3. DILUTION. Generally speaking D-19 is used undiluted. Dilution can be used to certain effects, but experimentation would need to be undertaken.
4. RECOMMENDED DEVELOPING TIMES. As always, developing times vary based on a considerable number of factors. The times below are simply starting points for experimentation using the undiluted stock solution...
   a. 1 EI ~ 2.00 minutes
   b. 25 EI ~ 3.00 minutes
   c. 100 EI ~ 5.00 minutes
   d. 200 EI ~ 6.5 minutes

[3] Taken from Photographic Lab Handbook, 5th Edition (Carroll, John S. - 1979)

Kodak D-76[4]

Perhaps the most commonly used black and white developer ever engineered, D-76 is a highly versatile developer which strikes a moderate balance between definition, contrast and tonal reproduction. It's energy levels make it well suited for both black and white positive and negative printing, but it is not recommended for reversal processing.

Technical Data	
Type	Developer (MQ based)
Approx. Shelf Life	3.00 months
Capacity	+/- 30.00 ft^2 per. 1,000.00 ml
pH	9.0
Stock Solution	
Water @ 52.0° C	750.0 ml
Metol [$C_7H_9NO \cdot 1/2H_2SO_4$]	2.0 g
Sodium Sulfite, Anhydrous [Na_2SO_3]	100.0 g
Hydroquinone [$C_6H_4(OH)_2$]	5.0 g
Borax [$Na_2B_4O_7$]	2.0 g
Water to make...	1,000.0 ml

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and dissolve a pinch (approx. 5.0 g per liter) of the sodium sulfite to the solution.
    c. While agitating the solution, dissolve each constituent in the order that they appear in the table above, making sure that each one is dissolved in it's entirely before the next addition.
2. STORAGE. Store the final stock solution in an airtight container. Protect from light when possible.
3. DILUTION. D-76 is traditional used undiluted. However, A variety of dilutions can be made from the stock solution, depending on the desired effect.
4. RECOMMENDED DEVELOPING TIMES. As always, developing times vary based on a considerable number of factors. The times below are simply starting points for experimentation using the undiluted stock solution...
    a. 1 ISO ~ 2.5 minutes
    b. 25 ISO ~ 4.0 minutes
    c. 100 ISO ~ 6.0 minutes
    d. 200 ISO ~ 8.0 minutes

[4] Taken from Photographic Lab Handbook, 5th Edition (Carroll, John S. - 1979)

HF-1 (Hardening Fixer)[5]

This formula is a composed of plain hypo with a diluted quantity of F-5a Hardener.

Technical Data	
Type	Fixer (Hardening, Acidic)
Approx. Shelf Life	*indefinite*
Archival Working Capacity	+/- 50.00 ft^2 per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 52.0 C	750.0 ml
Sodium Sulfite, Anhydrous [Na_2SO_3]	19.0 g
Sodium Thiosulfate [$Na_2S_2O_3$]	240.0 g
Boric Acid, Crystals [H_3BO_3]	9.0 g
Potassium Alum, Dodecahydrate [$KAl(SO_4)_2.12(H_2O)$]	19.0 g
Acetic Acid (28% Solution) [CH_3COOH]	60.0 ml
Water to make...	1,000.0 ml

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and, while agitating, each constituent in the order that they appear in the table above, except for the acetic acid.
    c. Reduce the temperature of the solution to approx. 20.0 C and add the acetic acid slowly.
2. STORAGE. Protect from light when possible.
3. DILUTION. Diluting is not recommended for standard fixing procedures.
4. RECOMMENDED FIXING TIMES.
    a. All stocks ~ 7.0 minutes

[5] From Kevin Rice

CB-1 (Clearing Bath)[6]

CB-1 is a very basic formula for a clearing solution.

Technical Data	
Type	Rinse (Ionic)
Approx. Shelf Life	indefinite
Archival Working Capacity	+/- 200.00 ft^2 per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 52.0 C	750.0 ml
Sodium Sulfite, Anhydrous [Na_2SO_3]	100.0 g
Sodium Bisulfite [$NaHSO_3$]*	25.0 g
Water to make...	1,000.0 ml

**The sodium bisulfite was originally included in this formula to act as a buffer for the solution as it was found that an unbuffered solution lead to excessive swelling of emulsions. However, given today's emulsions, this may not be as significant of an issue. Therefore, it is perfectly safe to exclude this constituent from the formula if needed.*

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and, while agitating, each constituent in the order that they appear in the table above.
2. STORAGE. Protect from light when possible.
3. DILUTION. A dilution of 1:9 (i.e. 1 part stock to 9 parts water) is recommended. Discard immediately after use.
4. RECOMMENDED CLEARING TIMES.
    a. All stocks ~ 1.0 minute

[6] From Kevin Rice

R9 Reversal Bleach[7]

This formula is a dichromate based, reducing bleach. It is the most commonly quoted formula for use in reversal processing. Additionally, it is a useful cleaner of labware. However, the formula is highly toxic.

Technical Data	
Type	Bleach (Reducer), Dish Cleaner
Approx. Shelf Life	*indefinite*
Archival Working Capacity	+/- 200.00 ft^2 per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 20.0 C	750.0 ml
Potassium Dichromate ($K_2Cr_2O_7$)*	9.5 g
Sulfuric Acid, 100% (H_2SO_4)**	12.0 ml
Water to make...	1,000.0 ml

**Carcinogenic compound: Always handle with full body, eye and respiratory protection.*

***Concentrated acid: Always handle with full body and eye protection. Never add water to acid -- always add acid to water.*

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. While agitating, add each constituent in the order that they appear in the table above.
2. STORAGE. Protect from light when possible.
3. DILUTION. Diluting is not recommended.
4. RECOMMENDED BLEACHING TIMES.
    a. All stocks ~ 2.0 minutes

[7] Taken from Photographic Lab Handbook, 5th Edition (Carroll, John S. - 1979)

Conversions

Surface Area of Motion Picture Film

S8mm x 100 ft. = 2.62 ft²
16mm x 100 ft. = 5.25 ft²
35mm x 100 ft. = 11.50 ft²

Temperature

[°C] = ([°F] − 32) × (5/9)
[°F] = ([°C] × (9/5)) + 32

Volume

Milliliter (ml) = Liter (L) * 1000.0
Milliliter (ml) = US Fluid Ounces (fl.oz) * 29.6
Milliliter (ml) = UK Fluid Ounces (fl.oz) * 28.4

Liter (L) = US Gallon * 3.79
Liter (L) = UK Gallon * 4.55

US Fluid Ounces (fl.oz) = ml * 0.0338
UK Fluid Ounces (fl.oz) = ml * 0.0352

UK Gallon = Liter (L) * 0.22
US Gallon = Liter (L) * 0.264

Mass

Grams (g) = Kilograms (kg) * 1000.0
Grams (g) = Ounces (oz.) * 28.35
Grams (g) = Grains (gr) * 0.0648
Grams (g) = Pound (lb) * 453.592

Ounces (oz.) = Grams (g) * 0.0354
Ounces (oz.) = Pound (lb) * 16

Grains (gr) = Grams (g) * 15.432
Grains (gr) = Ounces (oz.) * 437.5

Mass to Liquid Percentages

$M\ [g] = V_R\ [ml] * (\%_R / 100)\ [g/ml]$

Where $\%_R$ is the required percentage, V_R is the required volume in milliliters and M is the mass of the dry ingredient in grams. EXAMPLE: You want a 1 liter, 10% solution of potassium bromide. Therefore…

$$M = 1000\ ml * (10 /100)\ g/ml$$
$$M = 100.0\ g$$

...thus, dissolve 100.0 g to 1000.0 ml to arrive at a 10% solution.

Liquid Percentage Conversions

$V_S = (\%_R / \%_S) * V_R$

Where V_S is the volume of stock needed for dilution in, $\%_R$ is the required percentage, $\%_S$ is the stock percentage and V_R is the required volume. EXAMPLE: You have 28% acetic acid, but the recipe calls for 100.0 ml of 3% acetic acid. Therefore...

$$V_s = (3/28) * 100.0\ ml$$
$$V_s = 10.714\ ml$$

...thus, substitute the 100.0 ml of 3% acetic acid called for in the recipe with 10.714 ml of 28% acetic acid.

Units and Measurements

Relative Atomic Mass (A_r)

Relative atomic mass is, in it's most basic sense, the sum of each subatomic particles mass (i.e the mass of each proton, neutron an electron) within a given atom. It's value is expressed in atomic mass units (u) which is defined as 1/12th of a Carbon-12 atom at rest.

Mole (mol)

The mole is a unit of measurement used to express the amount of a chemical substance. For example, the reaction of di-hyrogen and di-oxygen to form water is written in the following equation:

$$2\ H_2 + 1\ O_2 \rightarrow 2\ H_2O$$

...whereby 2 mol di-hydrogen (H_2) + 1 mol di-oxygen (O_2) forms 2 mol water (H_2O). Additionally, we can also say that within 1 mol H_2O, there are 2 mol hydrogen (H) and 1 mol oxygen (O). etc..

Furthermore, a mole is defined as the amount of any substance containing as many specified elementary entities (e.g. atoms, ions, molecules, electrons, etc) as there are atoms in 12 grams of Carbon-12. This number directly correlates to the Avogadro Constant, $6.02214129(27)\times10^{23}$. Therefore...

$$1 \text{ Mol of X} = 6.02214129(27)\times10^{23} \text{ of X (whether X be an ion, molecule, atom, etc…)}$$

Molarity (c_i)

Molarity (a.k.a. molar concentration) is the amount of a constituent within a mixture (typically in units mol) divided by the volume of the mixture. The calculation for molarity is written as such:

$$c_i = n_i / V$$

...whereby c_i is molarity, n_i is the amount of the constituent in moles, and V is the volume of the mixture.
The unit for molarity is M and is equivalent to 1 mol / 1 Liter. Thus...

$$0.5 \text{ mol } AgNO_3 / 2 \text{ Liter} = 0.25 \text{ M } AgNO_3.$$

Molecular Mass

Molecular mass (a.k.a. Molecular Weight) is the sum of the relative atomic masses of each constituent atom multiplied by the number of moles of that element in a molecular formula. For example, water has the molecular formula H_2O. In order to calculate its molecular mass, we must figure the relative atomic masses of hydrogen and oxygen...

$$A_r\ H = 1.01\ u$$
$$A_r\ O = 16.00\ u$$

thus...

$$A_r\ H_2O = (2 \times A_r\ H) + (1 \times A_r\ O)$$
$$A_r\ H_2O = (2 \times 1.01\ u) + (1 \times 16.00\ u) = 18.02\ u$$

Molar Mass

Molar mass is the mass of 1 mol of any given substance. Conveniently, this is equal to its molecular mass in units gram. So, for example, with Silver Nitrate ($AgNO_3$), which has a molecular mass of 169.87 u, we can suggest that…

$$1 \text{ Mol AgNO3} = 169.87 \text{ grams } AgNO_3$$

Filmmakers and Selected Works

- Ben Donahue [researcher]
- Alex Mackenzie (http://www.alexmackenzie.ca/)
    - *Logbook* (2011)
    - Various performances
- Lindsay McIntyre
- Robert Schaller (http://www.robertschaller.org/)
    - *Triptych* (1996) [Gum Bichromate Emulsion]
    - *If Not One and One* (1999) [Gum Bichromate Emulsion]
    - *To the Beach* (1999) [Gum Bichromate Emulsion]
- Esther Urulus (http://estherurlus.hotglue.me/)
    - *Konrad & Kurfurst* (2014)

Chemical Suppliers

- ArtCraft Chemicals (http://www.artcraftchemicals.com/) -- *New York based photochemical supplier with a good selection and good prices, particularly for silver nitrate.*
- The Science Company (http://www.sciencecompany.com/) -- *Denver based chemistry and lab equipment supplier. Higher prices than most, but convenient if working in Colorado.*
- Photographers Formulary (http://stores.photoformulary.com/) -- *Montana based photochemical supplier with a moderate selection and good prices. Also sells kits and books.*
- Nymoc Products Co. (https://plus.google.com/111988851146358298635/about?hl=en) -- *Toronto based chemical supplier with the widest selection at the highest cost.*

Literature

The following selection of literature is a fairly comprehensive list of text relating to the process of emulsion making and it's related sciences. Some of these text are highly recommended and have been indicated as such with an asterisk (*) Additionally, any hyperlinked text are available to download from Process Reversals website at http://processreversal.org/literary-resources/

- Practical Guides to Emulsion Making
  These text are recommended for those interested in practical examples and insights into creating emulsions...
    - *Re:inventing the Pioneers: Film Experiments on Handmade Silver Gelatin Emulsion* (Urulus, Esther - 2013)*
    - *Making, Coating and Processing a Simple Gelatin Emulsion* (Osterman, Mark - 2007)
    - *Photographic Emulsion Making, Coating & Testing* (Mowery, Ron - 2009)
    - *Dye Transfer Materials* (Browning, James - 1998)
    - *Silver Gelatin: A User's Guide to Liquid Photographic Emulsions* (Reed, Martin; Jones, Sarah - 2001)

- Historic Emulsion Text
  These text are recommended for those seeking historical context to the emulsion making process. Many of them will discuss emulsion making techniques and formulas, but it's important to understand that any literature dealing with emulsion published before the 1940's assumes the use of photograde ACTIVE gelatin, which is no longer produced. Everything following that assumes the use of inert gelatin.
    - *The Silver Sunbeam* (Towler, John - 1864)
    - *Modern Dry Plates* (Eder, J.M. - 1881)
    - *Photography with Emulsions* (Abney, William De W. - 1885)
    - *Dry Plate Making for Amateurs* (Sinclair, George L. - 1886)
    - *Photographic Emulsions* (Wall, E.J. - 1929)
    - *The Photographic Emulsion* (Carroll, B.H.; Hubbard, D.; Kretschman, C.M. -1934)
    - *Photographic Emulsion Technique* (Baker, T. Thorne - 1941)*
    - *The Theory of the Photographic Process* (Mees, C.E. Kenneth - 1942)
    - *Making Kodak Film* (Shanebrook, Robert L. - 2012)

- Emulsion Chemistry & Theory
  These text are recommended for those interested in studying the theory and science of emulsion making. While
  - *Film Coating Theory* (Deryagin, B.V.; Levi, S.M. - 1964)
  - *Making and Coating Photographic Emulsions* (Zelikman, V. L.; Levi, S. M. - 1964)
  - *Photographic Gelatin* (Croome, R.J.; Clegg, F.G. - 1965)
  - *Photographic Emulsion Chemistry* (Duffin, G.F. - 1966)*
  - *Photographic Sensitivity: Theory and Mechanisms* (Tadaaki, Tani - 1995)*

- Sensitometry
  - *General Sensitometry* (Gorokhovskii, Yu. N.; Levenberg, T.M. - 1965)
  - *Photographic Sensitivity: Theory and Mechanisms* (Tadaaki, Tani - 1995)

- Photochemistry
  - *Photographic Processing Chemistry* (Mason, L.F.A. - 1966)
  - *Motion Picture and Television Film: Image Control and Processing Techniques* (Corbett, D.J. - 1968)*
  - *Developing: The Negative Technique* (Jacobson, C.I.; Jacobson, R.E. -1976)
  - *Photographic Lab Handbook, 5th Edition* (Carroll, John S. - 1979)
  - *The Film Developing Cookbook* (Tropp, Bill; Anchell, Stephen G.-1998)*
  - *The Darkroom Cookbook, 3rd Edition* (Anchell, Stephen G. - 2009)*

- Artist Run Film Labs
  - *Kinetica: Lieux d'Experimentations Cinematographiques en Europe* (Gran Lux - 2011)

Web Resources

- Analog Photographers User Group (APUG.org) -- *This website houses the most popular forum relating to analog photographer. While not specifically relating to motion picture film, there are many conversations and researchers of interest. Frequent user Ron Mowery (http://www.apug.org/forums/members/photo-engineer/) is particularly informative on the theory and practice of emulsion making and has contributed heavily to the APUG subsection on Silver Gelatin Based Emulsion Making (http://www.apug.org/forums/forum205/). To subscribe to the forum, follow the instructions here: http://www.apug.org/forums/register.php*
- The Light Farm (thelightfarm.com) --
- Film Labs (filmlabs.org) -- *This website houses information on various artist run film labs around the world and is also the host of the "film labs forum," a subscription based mailing list featuring discussions on all varieties of lab related subjects. To subscribe to the forum, follow the instructions posted here: https://listes.domainepublic.net/listinfo/forum*
- Graphic Atlas (graphicsatlas.org) -- *This website is dedicated to the documentation of various photographic processes and contains a very impressive collection of articles and images relating to the identification and archival handeling of various photogrpahic images. http://www.graphicsatlas.org/compareprocesses/*
- Molecular Weight Calculator