# The SOLUTION for All of Your Buffer Needs

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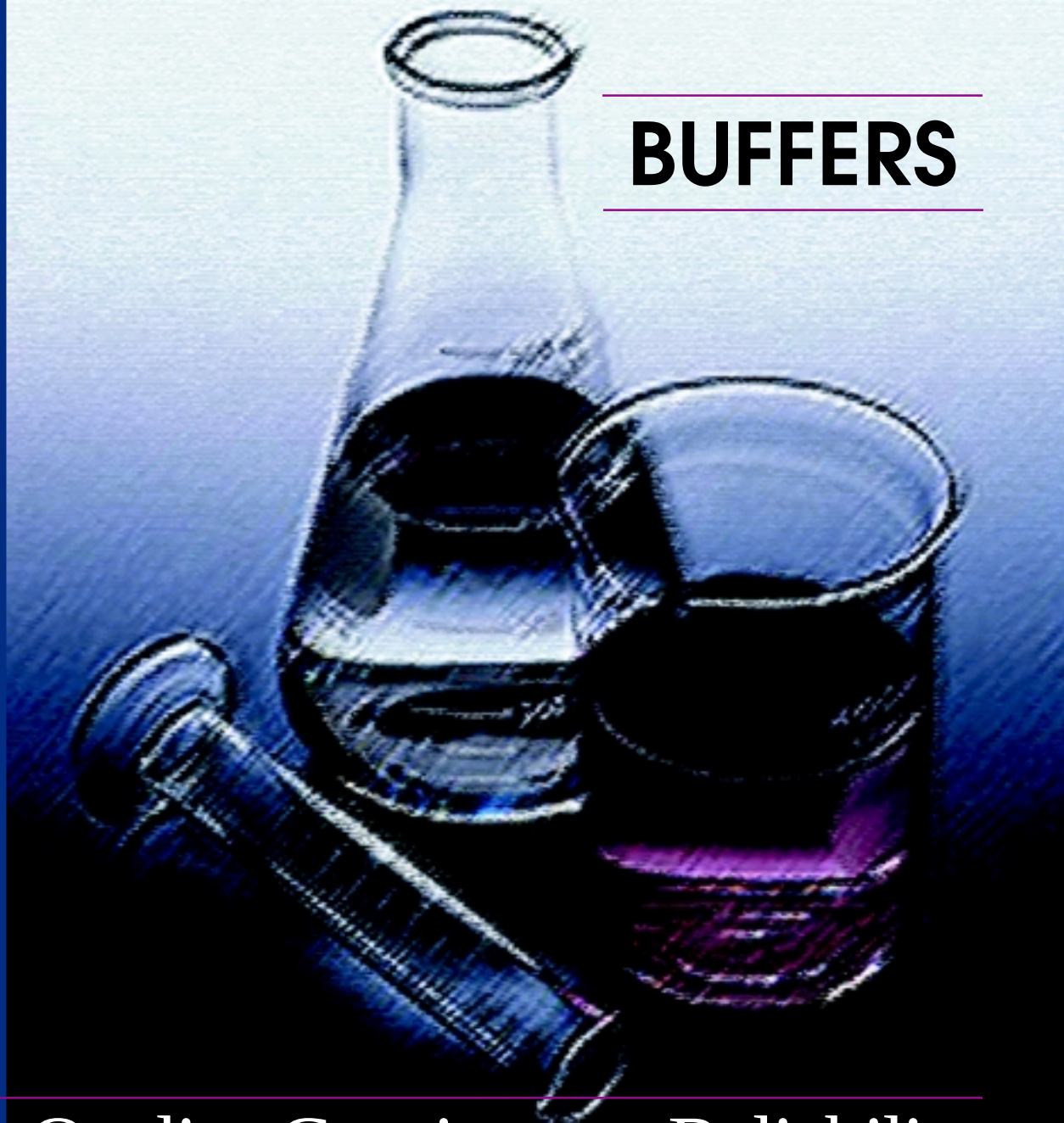

## BUFFERS

Quality, Consistency, Reliability

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# Purity, Reproducibility, Availability

# Introduction to Buffers (Part 1)

*Biological systems rely upon chemical interactions between life-sustaining biomolecules and water. The biochemical properties of biomolecules (which may be either free ions, small molecules or large macromolecules) depend upon the presence of chemical moieties which supply a positive or negative charge to the molecules and allow them to interact with the ionizable components of water.*

## What are Buffers and Why are They Important?

Most simply defined, a buffer is composed of a weak acid and its conjugate base. A buffer is an aqueous solution containing partly neutralized weak acids or bases that shows little change in pH when small amounts of strong acids or bases are added.

The concentration of hydrogen ions is of critical importance in biological and chemical systems. Measurement of pH is actually another way of expressing the concentration of hydrogen ions $[H^+]$ in a solution. Hydrogen ion concentrations have important implications in cell metabolism by affecting the rate of enzymatic reactions and the stability of biological molecules. For example, maintenance of an appropriate pH range in tissue culture media is critical to the growth and viability of all cultured cells.

The efficiency of many chemical separations and the rate of many chemical reactions are ruled by the pH of the solution. Buffers can be used to control the rate and yields in organic synthesis.

The hydrogen ion concentration is also an important parameter to control in numerous laboratory research techniques such as: electrophoresis, chromatography, and immunoassays. Uncontrolled pH can result in unsuccessful immunoassays since the required protein-protein interactions cannot occur efficiently outside the range of physiological pH.

## pH:

The ionization of water is a reversible reaction which can be described as the dissociation of $H_2O$ into its component ion products $[H^+]$ and $[OH^-]$. The equilibrium of this reaction ($K_w$) can be described in terms of the ion products where $[H^+]\ [OH^-] = K_w = 1 \times 10^{-14}\ M^2$. At neutral conditions and a temperature of 25°C, $[H^+] = [OH^-] = 1 \times 10^{-7}$ M, or pH = 7.0. The hydrogen ion concentration of a solution is usually expressed as pH ($-\log [H^+]$). Most biological systems have pH values between 6.5 and 8.0, while biochemical reactions may occur optimally at pH values ranging from 4.5 to 9.7. The optimal pH of a system depends upon the chemical nature of the ionizable groups in the reactive molecules.

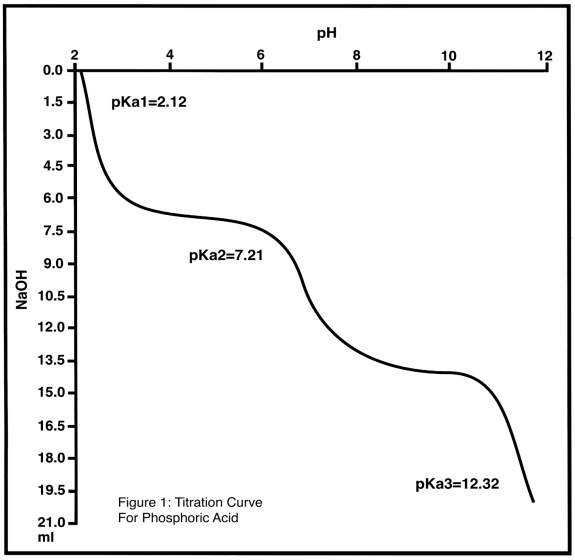


Figure 1: Titration Curve For Phosphoric Acid

## $pK_a$:

Many biologically important molecules contain chemical constituents which act as weak acids or bases in an aqueous solution. While strong acids dissociate completely into their component ion groups, weak acids dissociate incompletely and form an equilibrium between the weak acid and its conjugate base. For example, formic acid (HCOOH) dissociates into $[H^+]$ and $[COOH^-]$ where the equilibrium constant ($K_a$) for the weak acid can be described mathematically as:

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[H^+][COOH^-]}{[HCOOH]}$$

$$\text{and } pK_a = -\log K_a.$$

From this relationship, we see that the $pK_a$ value will vary inversely with the strength of the acid. Substitution into this equation gives the Henderson-Hasselbach equation, where

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

When 50% of a weak acid is dissociated, $[A^-] = [HA]$ and the $\log \frac{[A^-]}{[HA]}$ will be zero.

Thus, the $pK_a$ of weak acid will be equal to its pH at 50% dissociation. This relationship can be used to determine the $pK_a$ of a weak acid. For example, if a 1M solution of formic acid is half neutralized with 0.5M base such as NaOH, the resulting pH should be equal to 3.75, the $pK_a$ of formic acid. Because of the above relationship between weak acid dissociation and $pK_a$, $pK_a$ values approximate the midpoint in pH values for effective buffering.

While many compounds express simple ionic interactions and linear acid-base titration curves in aqueous solution, some compounds such as phosphoric acid are polybasic in nature and exhibit multiphasic transitions during titration **(Figure 1)**. Each midpoint between transition points in the titration curve represents a different $pK_a$ value for the solution. Because of their unique chemical properties, polybasic solutions often possess multiple $pK_a$ values which are useful in buffer selection.

# Introduction to Buffers (Part 2)

## Buffers and Buffering Range

Buffers consist of two ionic components, a weak acid (the proton donor) and a corresponding base (the proton acceptor). The ionic character of an aqueous buffer makes the solution relatively resistant to changes in pH upon the addition of small amounts of exogenous acid or base. The most effective pH range for a buffer is generally one pH unit and is centered around the $pK_a$ for the system. This relationship is important in choosing a buffer. For example, if a procedure calls for a pH of 3.75, formic acid ($pK_a$ = 3.75 at 25°C) would be a good choice of a buffer. Because pH = $pK_a$ at 50% dissociation, a solution of 0.01M formic acid would contain equal amounts of $[A^-]$ and [HA] at pH = 3.75. If half the [HA] is neutralized to $[A^-]$, [HA] = 0.0025M and $[A^-]$ = 0.0075M.

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$= 3.75 + \log \frac{0.0075}{0.0025}$$

$$= 3.75 + 0.48$$

$$= 4.23$$

This relationship defines the buffering range and capacity of a 0.01M solution of formic acid. In this system, no more than 0.0025 equivalents of acid can be neutralized before the buffer loses its capacity to maintain pH in the desired range.

The buffering range of a solution depends upon chemical interactions between the ionic components of water and the dissolved compounds. Both the solvent properties of water and the dissolution of a buffering compound change slightly with shifts in temperature and result in the alteration of solution pH values.

### CHOOSING BUFFERS:

(1) The $pK_a$ of the buffer should be near the desired midpoint pH of the solution.

(2) The capacity of a buffer should fall within one to two pH units above or below the desired pH values. If the pH is expected to drop during the procedure, choose a buffer with a $pK_a$ slightly lower than the midpoint pH. Similarly, if the pH is expected to rise, choose a buffer with a slightly elevated $pK_a$.

(3) The concentration of the buffer should be adjusted to have enough capacity for the experimental system.

(4) The pH of the buffer should be checked at the temperature and concentration which will be used in the experimental system.

(5) No more than 50% of the buffer components should be dissociated or neutralized by ionic constituents which are generated within or added to the solution.

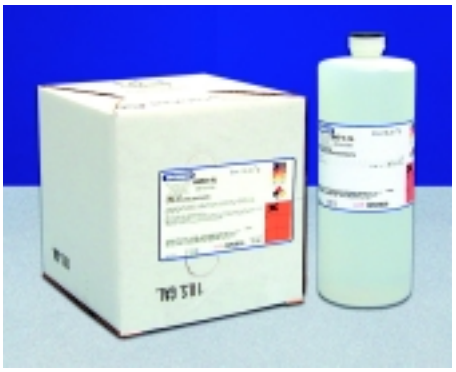
(6) Buffer materials should not absorb light between the wavelengths of 240-700 nm.

Although the change in pH which results from temperature variation may seem insignificant, such small changes may be critical within a biological system. For this reason, buffers should always be prepared and titrated to the correct pH at the operating temperature of the experimental system.

# Biological Buffers

**Table 1. Common Biological Buffers and their Associated $pK_a$ Values**

| BUFFER | $pK_a$ at 25°C |
|---|---|
| Phosphoric Acid | 2.12 ($pk_a1$) |
| Citric Acid | 3.06 ($pk_a1$) |
| Formic Acid | 3.75 |
| Succinic Acid | 4.19 ($pk_a1$) |
| Citric Acid | 4.76 ($pk_a2$) |
| Acetic Acid | 4.75 |
| Citric Acid | 5.40 ($pk_a3$) |
| Succinic Acid | 5.57 ($pk_a2$) |
| Imidazole | 7.00 |
| Phosphoric Acid | 7.21 ($pk_a2$) |
| Tris | 8.30 |
| Glycylglycine | 8.40 |
| Boric Acid | 9.24 |
| Phosphoric Acid | 12.32 ($pk_a3$) |



# Biological Buffers

## General Considerations:

Many biological systems generate and consume hydrogen ions as by-products of their cellular reactions, yet respond dramatically to small changes in environmental pH. To maintain a physiologically relevant pH (pH = 6.0-8.5) under such dynamic conditions, in vitro biological systems must be stabilized by the incorporation of buffers that undergo reversible protonation. Many early buffers were not suitable for biological applications because the pH of the solutions depended upon the concentration of the ionic components and the temperature of the solution. Moreover, the $pK_a$ values of many of these buffers were outside physiological pH ranges. For illustration, many early biological buffers and their associated $pK_a$ values are summarized in **Table 1**.

In 1966, Good et al. described 12 buffers which were useful for most common biological applications, having $pK_a$ values between 6.1 and 8.4. Most of these buffers were zwitterionic, capable of possessing both positive and negative charges. The nature of the original Good's buffers made them particularly suitable for biological applications because their buffering capacity was independent of temperature and concentration. They were very soluble in water but poorly soluble in organic solvents. This property made it difficult for the buffers to traverse cellular membranes or accumulate within biological systems. The reduced ion effects observed with these buffers allowed the preparation of solutions from concentrated stocks with minimal pH effects from the dilution of buffer components. A list of these zwitterionic buffers and their $pK_a$ values are summarized in **Table 2**.

**Table 2. Zwitterionic Buffers and their Associated $pK_a$ Values and Useful pH Ranges**

| BUFFER | $pK_a$ at 25°C | Useful pH Range |
|---|---|---|
| MES | 6.15 | 5.50-6.50 |
| Bis-Tris | 6.50 | 5.80-7.30 |
| PIPES, Na Salt | 6.80 | 6.10-7.50 |
| ACES | 6.88 | 6.00-7.50 |
| MOPS | 7.20 | 6.50-7.90 |
| TES | 7.40 | 6.80-8.20 |
| HEPES, Na Salt | 7.55 | 6.80-8.20 |
| HEPPS | 8.00 | 7.30-8.70 |
| Tricine | 8.15 | 7.80-8.80 |
| Bicine | 8.35 | 7.60-9.00 |
| CHES | 9.50 | 8.60-10.00 |
| CAPS | 10.40 | 9.70-11.10 |

The determination that the precursor compounds required for the synthesis of some zwitterionic buffers were carcinogenic led to the synthesis of hydroxyl derivatives of the buffers by Ferguson et al. (1980). These compounds were found to be compatible to a number of biological systems while expressing better chemical stability and improved solubility over the earlier Good's buffers. The most useful hydroxyl buffers are listed in **Table 3** with their associated $pK_a$ values. Ferguson et al. (1980) found that many chemical properties of the new zwitterionic buffers were advantageous to biological systems.

## Practical Considerations:

Because many zwitterionic compounds exhibit effects upon biological systems which are unrelated to their pH stabilization properties, factors other than $pK_a$ need to be considered when choosing a biological buffer. It is recommended that biological investigations employ a wide range of buffers or pH conditions to verify that the observations are not distorted by the choice of buffer. Before eukaryotic cells are used in experiments, the survival of the cells should be tested over a seven-day period at both low and high density seeding. At low densities, cells will be extremely sensitive to low levels of toxicity which may occur in certain buffers. Growth and viability of the cells at higher densities (or after 4-5 days growth from a less concentrated cell population) will demonstrate the ability of the buffer to support cell metabolism at higher cell densities and maintain pH at increased metabolite concentration. This is an important characteristic of a maintenance buffer for cells being used for weekly subculturing.

| Biological Buffers | Code | Size |
|---|---|---|
| Boric Acid | 0588 | 500 g<br>1 kg<br>2.5 kg |
| Citric Acid, Trisodium Dihydrate | 0101 | 1 kg<br>2.5 kg |
| Formic Acid | 0961 | Call |
| Glycine | 0167 | 1 kg<br>5 kg |
| Imidazole | 0527 | 10 g<br>50 g<br>100 g |
| Phosphoric Acid | 0239 | Call |
| Succinic Acid, Disodium Salt, Anhydrous | E288 | Call |
| Succinic Acid, Disodium Salt, Hexahydrate | 0477 | Call |
| Succinic Acid, Free Acid | 0165 | 500 g<br>2.5 kg |
| Tris Acetate | 0189 | 100 g |
| Tris Hydrochloride | 0234 | 500 g<br>1 kg |

**Table 3. Hydroxyl Zwitterionic Buffers and Associated $pK_a$ Values & Useful pH Ranges**

| BUFFER | $pK_a$ at 25°C | Useful pH Range |
|---|---|---|
| MOPSO | 6.88 | 6.20-8.60 |
| DIPSO | 7.60 | 7.00-8.20 |
| HEPPSO | 7.80 | 7.10-8.50 |
| POPSO | 7.80 | 7.20-8.50 |
| AMPSO | 9.00 | 8.30-9.70 |
| CAPSO | 9.60 | 8.90-10.30 |

# Electrophoresis Buffers

## General Considerations:

Effective separation of nucleic acids and proteins by agarose or polyacrylamide gel electrophoresis depends upon the effective maintenance of pH within the matrix. Therefore, buffers are an integral part of any electrophoresis technique. In addition to their role in the maintenance of pH, buffers provide ions which are needed for electrophoretic migration.

## Nucleic Acid Electrophoresis:

Electrophoretic separation of DNA is dominated by the Tris-based buffers. Tris-Acetate EDTA (TAE; 0.04 M Tris-Acetate, 0.001M EDTA, pH = 8.0) is less expensive, but not as stable as Tris-Borate-EDTA. TAE gives better resolution of DNA bands in short electrophoretic separations and is often used when subsequent DNA isolation from the matrix is desired. Tris-

Borate-EDTA (TBE; 0.089M Tris Base, 0.089M Boric Acid, 0.002M EDTA, pH = 8.3) is used for polyacrylamide gel electrophoresis of smaller molecular weight DNA (MW < 2000) and slab agarose gel electrophoresis of larger DNA where high resolution is not essential.

DNA sequencing requires the addition of urea to polyacrylamide gels to maintain the single stranded, denatured state of DNA required for reproducible resolution of the individual DNA bands. TBE has been the traditional buffer system for DNA sequencing projects though the borate component of the buffer is known to interact with glycerol which may be present in DNA samples after treatment with DNA polymerase or restriction enzymes. This interaction of borate with glycerol can cause distortion in the spacing and shape of the DNA bands in sequencing gels.

Gel electrophoresis of RNA presents some unique problems that are not observed with DNA samples. The propensity of RNA to form intramolecular secondary structures requires that the molecules be thoroughly denatured before application to the gel and maintained in a reduced condition throughout electrophoretic separation. Denaturation may be performed in 60-85% formamide solution at 65°C, but buffering is required or the RNA will degrade. Often, 0.5X TBE is used to buffer RNA samples during denaturation.

RNA electrophoresis requires the use of agarose gels containing a denaturing agent such as formaldehyde or glyoxal for maximum resolution of bands. Buffers are required to maintain a steady pH because the denaturing agents decompose during electrophoresis and alter the pH of the gel. RNA is unstable in slightly alkaline solution, so lower pH ranges are required in RNA gels. Thus, Tris-based buffers ($pK_a$ = 8.3) are unsuitable for RNA electrophoresis. MOPS buffer has a $pK_a$ = 7.2 and is the buffer of choice for denaturing gel electrophoresis of RNA. MOPS is available in a free acid and sodium salt form and works exceptionally well at concentrations of 20mM.

## Protein Electrophoresis:

Unlike nucleic acids, proteins exhibit both anionic and cationic characteristics which are highly dependent upon the pH of the medium for their biochemical activity. Small changes in the pH of a buffer can affect both the structure and the net charge of a protein molecule. Because of the dynamic relationship between a protein and ionic components in buffers, native gel electrophoresis of proteins requires a buffer choice based upon the pI of the protein. For this reason, there is no single buffer system for native gel electrophoresis of proteins.

| Electrophoresis Buffers | Code | Size |
|---|---|---|
| TAE Buffer, 25X Liquid Concentrate | 0796 | 1.6 L |
| TAE Buffer, Powder | 0912 | 40 L |
| TAE Buffer, 25X Ready-Pack™ | 0912 | 2 pk |
| TBE Buffer, Powder* | 0478 | 40 L |
| TBE Buffer, 10X Ready-Pack™ | 0478 | 2 pk |
| TBE Buffer, 10X Liquid Concentrate | 0658 | 4 L |
| TBE Buffer, 5X Liquid Concentrate | J885 | 1 L<br>4 L |
| TBE Buffer, 10X Ready-Pack™ | J490 | 2 pk |
| EZ TBE Buffer™, 50X Concentrate<br>(Each 10 ml Tablet Prepares 500 ml 1X TBE) | J752 | 10x10 ml |
| EZ TBE Buffer™, 50X Concentrate<br>(Each 20 ml Tablet Prepares 1 Liter 1X TBE) | J755 | 10x20 ml |
| TG Buffer, Powder | 0251 | 40 L |
| TG Buffer, 10X Ready-Pack™ | 0251 | 2 pk |
| TG Buffer, 10X Liquid Concentrate | 0307 | 4 L |
| TG-SDS Buffer, Powder | 0147 | 40 L |
| TG-SDS Buffer, 10X Ready-Pack™ | 0147 | 2 pk |
| TG-SDS Buffer, 10X Liquid Concentrate | 0783 | 4 L |
| TG-SDS Buffer, 5X Liquid Concentrate | E696 | 500 ml |
| TT Buffer, 10X Ready-Pack™ | E461 | 1 pk |
| TT Buffer, 10X Liquid Concentrate | E471 | 1 L |
| TT-SDS Buffer, 10X Ready-Pack™ | E457 | 1 pk |
| TT-SDS Buffer, 10X Liquid Concentrate | E449 | 1 L |

**NOTE:** 1 Ready-Pack prepares 1 L of the respective buffer concentrate.
*TBE Buffer (0478) is prepared using EDTA, Free Acid (0322). All other TBE Buffers are prepared using EDTA, Disodium Dihydrate (0105).

SDS is an anionic detergent that is added to samples to denature the proteins and produce a uniform negative charge on the molecules prior to denaturing protein gel electrophoresis. Treatment with SDS allows proteins to migrate through the electric field according to their approximate mass. Because the rate of protein migration depends upon interactions with ionic components of the buffer, even small changes in the pH of a buffer may alter the association of SDS with the protein and influence the molecular weight calculations as judged by denaturing gel electrophoresis. The addition of SDS (0.1% w/v) to Tris-Glycine (0.025M Tris Base; and 0.25M Glycine, pH = 8.3) or Tris-Tricine (0.1M Tris Base, and 0.1M Tricine) produces an excellent buffering system for denaturing protein gels.

# Molecular Biology Buffers

## Membrane Transfer:

The separation of proteins or nucleic acids by gel electrophoresis and subsequent transfer of macromolecules to nitrocellulose or nylon membranes allows scientists to study molecular interactions between defined subsets of molecules. Many characteristics of buffers that are important for gel electrophoresis are also important during direct blotting or transfer techniques, especially since the advent of electrophoretic transfer protocols. The binding of macromolecules to membranes is charge-dependent and relies upon the maintenance of a consistent pH in the transfer buffer. Without buffers, the directional migration of macromolecules and the reproducible transfer of larger molecules would be haphazard, at best. Recommended buffers for most common blotting techniques are shown in **Table 4**.

## Enzymatic Reactions:

Many biochemical reactions that are used in molecular biology require specialized buffers and salt optima. The general rules of choosing buffers (see *Introduction*) apply when a new experimental technique is being developed. Often, zwitterionic buffers are not required and many of the common biological buffers listed in Table 1 may be employed. An understanding of the pH optima for a specific enzyme and knowledge of the ionic products of the reaction should be considered when choosing the buffer. Multiple buffers should be tested to verify that the results are not an artifact of the buffer system. When buffers change between protocols, chromatographic desalting, extraction or dialysis are recommended to minimize the ionic crossover between buffers and maximize enzymatic activity.

## Nucleic Acid and Protein Isolation/Purification:

Many of the common specialty solutions which are used for the isolation and purification of nucleic acids are readily available. These solutions include RNase-free sodium acetate for the precipitation of non-degraded RNA, NaOH-SDS solution for the alkaline lysis method of plasmid purification from bacterial cells, sodium chloride and potassium acetate for the precipitation of purified DNA, and nuclease-free water for purification and biochemical work with all nucleic acids. Solutions used in protein purification and isolation are also available, including glycine for use in protein gel electrophoresis and 10X TG-SDS Liquid for protein blotting.

| Molecular Biology Buffers & Reagents | Code | Size |
|---|---|---|
| 20% Glucose | E545 | 100 ml |
| 20% Sucrose | E543 | 100 ml |
| Ammonium Acetate, 10M | J515 | 100 ml<br>250 ml |
| Calcium Chloride, 1M Sterile | E506 | 100 ml<br>500 ml |
| Complete Cell Lysis Solution | E203 | 5 ml |
| EDTA, 0.5M pH 8.0 | E177 | Call |
| GTE (TE-Glucose) | E524 | 100 ml<br>500 ml |
| Magnesium Chloride, 1M Sterile | E525 | 100 ml<br>500 ml |
| Magnesium Sulfate, 1M Sterile | E541 | 100 ml |
| NaOH/SDS Lysis Solution | J611 | 500 ml |
| Potassium Acetate Solution | E130 | 500 ml |
| Potassium Acetate, 1M | J616 | 250 ml |
| SM Buffer | J614 | 500 ml |
| Sodium Acetate, 2M, pH 4.2 | E502 | 100 ml |
| Sodium Acetate, 3M, pH 5.2 | E521 | 100 ml |
| Sodium Acetate, 3M, pH 7.0 | J618 | 100 ml |
| Sodium Chloride, 5M | E529 | 100 ml<br>500 ml |
| STET Buffer | J613 | 500 ml |
| TE Buffer | E112 | 100 ml<br>500 ml |
| TEN (STE) | J384 | Call |
| TM Buffer | J615 | 500 ml |
| TNT Buffer | J612 | 500 ml |
| Tris Base | 0826 | 500 g<br>1 kg |
| Tris, 0.1M pH 7.4 | E553 | 100 ml<br>500 ml |
| Tris, 1M pH 8.0 | E199 | 100 ml<br>500 ml |
| Water, Nuclease-Free | E476 | 500 ml |

**Table 4. Buffers for Common Blotting Techniques**

| Technique | Recommended Buffer(s)[a] |
|---|---|
| **Proteins** | |
| Transfer to Membranes | Tris-Glycine or Tris-Tricine (pg. 18.64) |
| Immunoblotting | Phosphate Buffered Saline (PBS) (pg. 18.70) |
| **Nucleic Acids** | |
| Transfer to Membranes | Sodium Chloride-Sodium Citrate (pg. 9.38) |
| Southern Blotting | Sodium Chloride-Sodium Citrate (pg. 9.34) |
| Northern Blotting | Sodium Chloride-Sodium Citrate (pg. 7.46) |

[a] Additional solutions and buffers may be required to prepare membranes for blotting, to block nonspecific binding sites or to remove unbound macromolecules. These solutions may vary with the membrane type and manufacturer. The manufacturer's recommended buffers should be used for such ancillary procedures. Cited protocols are described in Sambrook, Fritsch and Maniatis (1989); page #'s are in parentheses after each buffer.

# Ultra Pure Buffers

## General Considerations:

All cellular and molecular protocols which depend upon buffers should use high quality reagents. For most biological or biochemical applications, buffers should not absorb light between the wavelengths of 240 and 700 nm.

For biological applications, especially eukaryotic tissue culture, they should be free of endotoxin and mycoplasma, low in free metal ions, and preferably contain an indicator dye to monitor pH changes visually.

For molecular and biochemical protocols, buffers should be free of proteinases, nucleases, and macromolecules, low in free metals, and devoid of other macromolecules that can interfere with the direct analysis of the experimental data.

| Ultra Pure Buffer Components | Code | Size |
|---|---|---|
| EDTA, Disodium Salt | 0105 | 500 g<br>1 kg<br>2.5 kg |
| EDTA, Free Acid | 0322 | 500 g<br>1 kg |
| Tris Base | 0497 | 500 g<br>1 kg<br>5 kg |


**REFERENCES:**

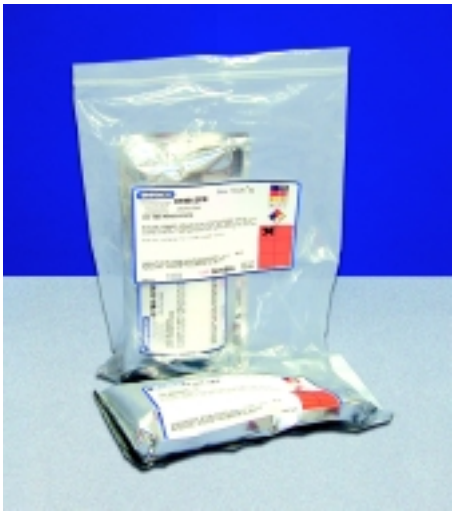
Good, N.E., et al. **Biochemistry** 5:467 (1966).
Ferguson, W.J., et al. **Anal. Biochem.** 104:300 (1980).
Sambrook, J., Fritsch, E.F. and Maniatis, T., **Molecular Cloning: A Laboratory Manual,** 2nd edition, Cold Spring Harbor Press (1989).


# Buffers for Blotting

## General Considerations:

High quality buffers for blotting provide a strong foundation for experimentation and discovery.

| Buffers for Blotting | Code | Size |
|---|---|---|
| PBS Tablets | E404 | 100 T<br>200 T |
| 10X PBS Ready-Pack™ | 0780 | 2 pk |
| 20X SSC Liquid | 0804 | 4 L |
| SSC Ready-Pack™ | 0794 | 2 pk |
| 20X SSPE Liquid | 0810 | 4 L |
| SSPE Ready-Pack™ | 0806 | 2 pk |
| TBS Ready-Pack™ | 0788 | 2 pk |



# Zwitterionic Buffers

## General Considerations:

Zwitterionic buffers were developed by N.E. Good to be used in a wide range of biological systems. The buffers' $pK_a$ values are at or near physiological pH; they are non-toxic to cells; and they are not absorbed through cell membranes. The buffers do not significantly absorb ultraviolet light, and they are relatively inexpensive. "Good's Buffers" are widely used in cell culture and other biological applications, and offer even further improvements in water solubility, high chemical stability, and compatibility in a number of biological systems (Ferguson et al., 1980).

| Zwitterionic Buffers | Code | Size |
|---|---|---|
| ACES | 0285 | 100 g<br>500 g |
| ADA | E232 | 25 g<br>100 g |
| ADA, Monosodium Salt | E239 | Call |
| AMPSO | J625 | 25 g<br>100 g |
| AMPSO, Sodium Salt | J624 | 25 g<br>100 g |
| BES | J196 | Call |
| Bicine | 0149 | Call |
| Bis-Tris | 0715 | 100 g<br>250 g<br>500 g |
| CAPS | 0365 | 250 g<br>500 g<br>1 kg |
| CAPS, Sodium Salt | J620 | 25 g<br>100 g |
| CAPSO | J623 | 25 g<br>100 g |
| CHES | 0392 | 100 g<br>500 g |
| CHES, Sodium Salt | E635 | Call |
| DIPSO | J591 | 25 g<br>100 g |
| Glycylglycine | 0137 | 100 g<br>250 g<br>1 kg |
| HEPES, Free Acid | 0511 | 50 g<br>250 g |
| HEPES, Low Sodium Salt | E383 | Call |
| HEPES, Sodium Salt | 0485 | 25 g<br>100 g<br>500 g |

| Zwitterionic Buffers (Continued) | Code | Size |
|---|---|---|
| HEPPES/EPPS | J588 | 25 g<br>100 g |
| HEPPSO | J587 | 25 g<br>100 g |
| MES | E169 | 100 g<br>250 g<br>500 g |
| MES, Anhydrous | E183 | Call |
| MES, Sodium Salt | X218 | Call |
| MOPS | 0670 | 100 g<br>250 g<br>500 g |
| MOPS, Sodium Salt | E413 | 25 g<br>100 g<br>250 g |
| MOPSO | J589 | 25 g<br>100 g |
| MOPSO, Sodium Salt | J563 | 25 g<br>100 g |
| PIPES | 0488 | Call |
| PIPES, Sodium Salt | 0169 | 100 g<br>250 g |
| POPSO | J597 | 25 g<br>100 g |
| POPSO, Sodium Salt | J590 | 25 g<br>100 g |
| TAPS | J562 | 100 g |
| TAPS, Sodium Salt | J598 | 25 g<br>100 g |
| TES | E133 | Call |
| TES, Sodium Salt | J527 | 25 g<br>100 g |
| Tricine | E170 | 100 g<br>250 g<br>500 g |

# BUFFERS

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