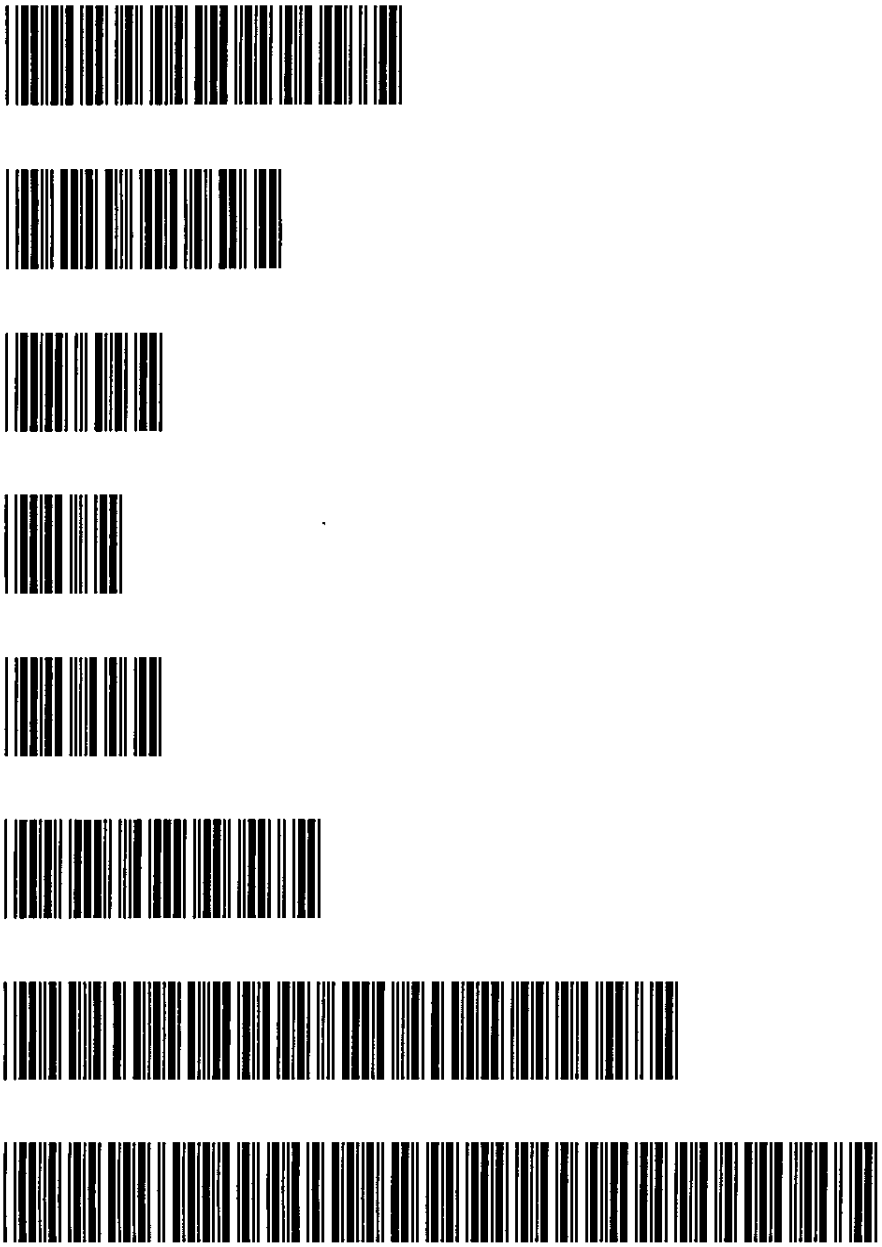


KSR 7/6/05 13:11
3:05-CV-00720 INVITROGEN CORP V. BIO RAD LABORATORIES
39
AMDCMP.

WILLEM SCHUURMAN (*Pro Hac Vice*)
GARY EWELL (*Cal. State Bar No. 104050*)
VINSON & ELKINS L.L.P.
2801 Via Fortuna, Suite 100
Austin, Texas 78746
Tel: (512) 542-8526
Fax: (512) 236-3243

JEFFREY D. LEWIN (*Cal. State Bar No. 68202*)
SULLIVAN HILL LEWIN REZ & ENGEL
550 West C Street, Suite 1500
San Diego, California 92102
Tel: (619) 233-4100
Fax: (619) 231-4372

Attorneys for Plaintiff
INVITROGEN CORPORATION

IN THE UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA (SAN DIEGO DIVISION)

INVITROGEN CORPORATION, Plaintiff, vs. BIO-RAD LABORATORIES, INC., Defendant.	Civil Action No.: **AMENDED COMPLAINT FOR PATENT INFRINGEMENT** DEMAND FOR JURY TRIAL

Invitrogen Corporation, Plaintiff, brings this action against Bio-Rad Laboratories, Inc. Defendant, and alleges in this Complaint as follows:

PARTIES

1. Plaintiff Invitrogen Corporation ("Invitrogen") is a corporation organized under the laws of Delaware having its principal place of business in Carlsbad, California.

2. Upon information and belief, Defendant Bio-Rad Laboratories, Inc. ("Bio-Rad") is a corporation organized under the laws of Delaware. Bio-Rad's headquarters are located at 1000 Alfred Nobel Dr., Hercules, California.

39

3. Upon information and belief, Bio-Rad has sales representatives assigned to territories within the Southern District of California for purposes of selling a variety of products to customers throughout those territories. Invitrogen is informed and believes that Bio-Rad has sold and continues to sell a variety of products within the Southern District of California, and that its contacts with the Southern District of California are continuous and systematic.

4. Upon information and belief, Bio-Rad has sold infringing products within the Southern District of California and has placed infringing products in the stream of commerce, knowing and expecting that such products would be sold and used in this judicial district.

JURISDICTION AND VENUE

5. This is an action for patent infringement under the patent laws of the United States, 35 U.S.C. §§ 1 *et seq.*

6. This Court has subject matter jurisdiction over this action pursuant to 28 U.S.C. §§ 1331(a) and 1338(a). The Court has personal jurisdiction over Bio-Rad, which is domiciled in this state.

7. Venue in this district is proper under 28 U.S.C. §§ 1391(b) and (c), and 1400(b).

FIRST CLAIM FOR RELIEF AGAINST BIO-RAD

Infringement of U.S. Patent No. 5,922,185

8. Plaintiff Invitrogen incorporates by reference and realleges the allegations of paragraphs 1 through 7 above.

9. Invitrogen is and has been owner by means of an assignment from inventors Timothy V. Updyke and Sheldon C. Englehorn of all right, title and interest in and to U.S. Patent No. 5,922,185, entitled "SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL," issued July 13, 1999 (the "'185 patent"). The '185 patent is attached hereto as Exhibit A.

10. Invitrogen is informed and believes that Bio-Rad has, since issuance of the `185 patent and without authorization from Invitrogen, used, offered for sale, sold, and/or imported into the United States, individually and/or as components of other products or systems articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems), embodying or employing the inventions of claims 1 through 5 and 8 of the `185 patent. Thus Bio-Rad has

knowingly committed acts of direct infringement of the '185 patent.

11. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 1 through 5 and 8 of the '185 patent, with instructions for their use, intending that the purchasers of these articles use them in the manner as instructed. Thus, Bio-Rad has knowingly induced others to commit acts of direct infringement of the '185 patent.

12. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 1 through 5 and 8 of the '185 patent, which articles are not a staple article of commerce or capable of a substantial non-infringing use, but rather have no substantial use other than to be used as intended in accordance with Bio-Rad's instructions. Thus, Bio-Rad has knowingly contributed to others' acts of direct infringement of the '185 patent.

13. Invitrogen has suffered damages as a result of Bio-Rad's infringement of the '185 patent and will continue to suffer damages as a result of Bio-Rad's continued infringement of the '185 patent.

14. Bio-Rad's infringement has caused and will continue to cause irreparable injury to Invitrogen for which there is no adequate remedy at law.

15. Invitrogen is informed and believes that Bio-Rad's infringement of the '185 patent is willful and will continue until enjoined by this Court.

SECOND CLAIM FOR RELIEF AGAINST BIO-RAD

(Infringement of U.S. Patent No. 6,162,338)

16. Invitrogen realleges and incorporates by reference the allegations of paragraphs 1 through 7 above.

17. Invitrogen is and has been owner by means of an assignment from inventors Timothy V. Updyke and Sheldon C. Englehorn of all right, title and interest in and to U.S. Patent No. 6,162,338, entitled "SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL,"

issued December 19, 2000 (the "'338 patent"). The '338 patent is attached hereto as Exhibit B.

18. Invitrogen is informed and believes that Bio-Rad has, since issuance of the '338 patent and without authorization from Invitrogen, used, offered for sale, sold, and/or imported into the United States, individually and/or as components of other products or systems articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems), embodying or employing the inventions of claims 14 and 15 of the '338 patent. Thus Bio-Rad has knowingly committed acts of direct infringement of the '338 patent.

19. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 14 and 15 of the '338 patent, with instructions for their use, intending that the purchasers of these articles use them in the manner as instructed. Thus, Bio-Rad has knowingly induced others to commit acts of direct infringement of the '338 patent.

20. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 14 and 15 of the '338 patent, which articles are not a staple article of commerce or capable of a substantial non-infringing use, but rather have no substantial use other than to be used as intended in accordance with Bio-Rad's instructions. Thus, Bio-Rad has knowingly contributed to others' acts of direct infringement of the '338 patent.

21. Invitrogen has suffered damages as a result of Bio-Rad's infringement of the '338 patent and will continue to suffer damages as a result of Bio-Rad's continued infringement of the '338 patent.

22. Bio-Rad's infringement of the '338 patent has caused and will continue to cause irreparable injury to Invitrogen for which there is no adequate remedy at law.

23. Invitrogen is informed and believes that Bio-Rad's infringement of the '338 patent is willful and will continue until enjoined by this Court.

THIRD CLAIM FOR RELIEF AGAINST BIO-RAD

Infringement of U.S. Patent No. 6,783,651

24. Plaintiff Invitrogen incorporates by reference and realleges the allegations of paragraphs 1 through 7 above.

25. Invitrogen is and has been owner by means of an assignment from inventors Timothy V. Updyke and Sheldon C. Englehorn of all right, title and interest in and to U.S. Patent No. 6,783,651, entitled "SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL," issued August 31, 2004 (the "'651 patent"). The '651 patent is attached hereto as Exhibit C.

26. Invitrogen is informed and believes that Bio-Rad has, since issuance of the '651 patent and without authorization from Invitrogen, used, offered for sale, sold, and/or imported into the United States, individually and/or as components of other products or systems articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems), embodying or employing the inventions of claims 2, 3, 4, 12 and 14 of the '651 patent. Thus Bio-Rad has knowingly committed acts of direct infringement of the '651 patent.

27. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 2, 3, 4, 12 and 14 of the '651 patent, with instructions for their use, intending that the purchasers of these articles use them in the manner as instructed. Thus, Bio-Rad has knowingly induced others to commit acts of direct infringement of the '651 patent.

28. Invitrogen is also informed and believes that Bio-Rad has knowingly and actively sold articles (including, but not limited to, Bio-Rad's Criterion™ XT gels and systems) embodying or employing the inventions of claims 2, 3, 4, 12 and 14 of the '651 patent, which articles are not a staple article of commerce or capable of a substantial non-infringing use, but rather have no substantial use other than to be used as intended in accordance with Bio-Rad's instructions. Thus, Bio-Rad has knowingly contributed to others' acts of direct infringement of the '651 patent.

29. Invitrogen has suffered damages as a result of Bio-Rad's infringement of the '651

patent and will continue to suffer damages as a result of Bio-Rad's continued infringement of the '651 patent.

30. Bio-Rad's infringement of the '651 patent has caused and will continue to cause irreparable injury to Invitrogen for which there is no adequate remedy at law.

31. Invitrogen is informed and believes that Bio-Rad's infringement of the '651 patent is willful and will continue until enjoined by this Court.

PRAYER FOR RELIEF

WHEREFORE, Invitrogen prays for judgment as follows:

1. that Bio-Rad has infringed the '185, '338, and '651 patents;

2. that Bio-Rad has induced infringement of the '185, '338, and '651 patents;

3. that Bio-Rad has contributed to the infringement of the '185, '338, and '651 patents;

4. that a preliminary and permanent injunction be issued against further infringement of the '185, '338, and '651 patents by Bio-Rad and its officers, agents, servants, employees, attorneys, and all persons in active concert or participation with it;

5. that Bio-Rad accounts and pays actual damages (but no less than a reasonable royalty) to Invitrogen for Bio-Rad's infringement of the '185, '338, and '651 patents;

6. that Bio-Rad pays treble damages to Invitrogen as provided by 35 U.S.C. §284;

7. that Bio-Rad pays Invitrogen's costs, expenses, and prejudgment interest as provided for by 35 U.S.C. §284;

8. that this case is exceptional within the meaning of 35 U.S.C. §285 and awarding Invitrogen its reasonable attorney fees; and

9. that Invitrogen be granted such other and further relief as the Court deems just and equitable.

June 30, 2005

Respectfully submitted,

WILLEM SCHUURMAN (*Pro Hac Vice*)
GARY EWELL (*Cal. State Bar No. 104050*)
TRACEY B. DAVIES (*Pro Hac Vice*)
TANYA DEMENT (*Pro Hac Vice*)
VINSON & ELKINS L.L.P.
2801 Via Fortuna, Suite 100
Austin, Texas 78746
Tel: (512) 542-8526
Fax: (512) 236-3243

JEFFREY D. LEWIN (*Cal. State Bar No. 68202*)
SULLIVAN HILL LEWIN REZ & ENGEL
550 West C Street, Suite 1500
San Diego, California 92102
Tel: (619) 233-4100
Fax: (619) 231-4372

Attorneys for Plaintiff
INVITROGEN CORPORATION

DEMAND FOR JURY TRIAL

Pursuant to Federal Rule of Civil Procedure 38, Plaintiff demands a jury trial on all issues triable of right by a jury.

June 30, 2005

Respectfully submitted,

WILLEM SCHUURMAN (*Pro Hac Vice*)
GARY EWELL (*Cal. State Bar No. 104050*)
TRACEY B. DAVIES (*Pro Hac Vice*)
TANYA DEMENT (*Pro Hac Vice*)
VINSON & ELKINS L.L.P.
2801 Via Fortuna, Suite 100
Austin, Texas 78746
Tel: (512) 542-8526
Fax: (512) 236-3243

JEFFREY D. LEWIN (*Cal. State Bar No. 68202*)
SULLIVAN HILL LEWIN REZ & ENGEL
550 West C Street, Suite 1500
San Diego, California 92102
Tel: (619) 233-4100
Fax: (619) 231-4372

584458_1.DOC

WILLEM SCHUURMAN (*Pro Hac Vice*)
GARY EWELL (*Cal. State Bar No. 104050*)
VINSON & ELKINS L.L.P.
2801 Via Fortuna, Suite 100
Austin, Texas 78746
Tel: (512) 542-8526
Fax: (512) 236-3243

DONALD G. REZ (*Cal. State Bar No. 82615*)
SULLIVAN HILL LEWIN REZ & ENGEL
550 West C Street, Suite 1500
San Diego, California 92102
Tel: (619) 233-4100
Fax: (619) 231-4372

Attorneys for Plaintiff
INVITROGEN CORPORATION

DAVID BILSKER (Bar No. 152383)
KATHARINE ALTEMUS (Bar No. 227080)
Howrey, LLP
525 Market Street, Suite 3600
San Francisco, CA 94105
Telephone: (415) 848-4900
Facsimile: (415) 848-4999

Attorneys for Defendant
BIO-RAD LABORATORIES, INC.

IN THE UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA (SAN DIEGO DIVISION)

INVITROGEN CORPORATION, Plaintiff, vs. BIO-RAD LABORATORIES, INC., Defendant.	Civil Action No.: 05 CV 0720 BTM (BLM) **ORDER GRANTING ENTRY OF PLAINTIFF INVITROGEN CORPORATION'S AMENDED COMPLAINT FOR PATENT INFRINGEMENT**

On this ___ day of _____, 2005, the Court finds that entry of Plaintiff's AMENDED COMPLAINT FOR PATENT INFRINGEMENT has been consented to by Defendant under Fed. R. Civ. P. 15(a). It is, therefore,

ORDERED that Plaintiff's AMENDED COMPLAINT FOR PATENT INFRINGEMENT shall be deemed filed on the date this ORDER is signed. It is further

ORDERED that Plaintiff's AMENDED COMPLAINT FOR PATENT INFRINGEMENT shall be answered by Defendant, Bio-Rad Laboratories, Inc. within ten (10) days of the date this ORDER is signed.

SIGNED this ____ day of _____, 2005.

_____

Judge Presiding

US005922185A

United States Patent [19]

Updyke et al.

[11] Patent Number: 5,922,185

[45] Date of Patent: *Jul. 13, 1999

[54] **SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL**

[75] Inventors: **Timothy V. Updyke**, Temecula; **Sheldon C. Engelhorn**, Cardiff-by-the-Sea, both of Calif.

[73] Assignee: **Novel Experimental Technology, Inc.**, San Diego, Calif.

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).
This patent is subject to a terminal disclaimer.

[21] Appl. No.: **08/730,678**

[22] Filed: **Oct. 11, 1996**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/221,939, Mar. 31, 1994, Pat. No. 5,578,180.

[51] **Int. Cl.**[6] **G01N 27/26**

[52] **U.S. Cl.** **204/468**; 204/466; 204/606

[58] **Field of Search** 204/456, 465, 204/466, 455, 450, 605, 606, 615, 468

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,948,743	4/1976	Monthony et al.	204/469
4,209,373	6/1980	Bluestein et al.	204/468
4,481,094	11/1984	de Castro et al.	204/180
4,504,641	3/1985	Nochumson	526/238.2
4,542,200	9/1985	Nochumson	526/238.2
4,699,705	10/1987	Ogawa et al.	204/469
4,950,708	8/1990	Hochstrasser	524/728
5,275,708	1/1994	Akins et al.	204/468
5,464,516	11/1995	Takeda et al.	204/456
5,578,180	11/1996	Engelhorn et al.	204/468

FOREIGN PATENT DOCUMENTS

0 087 995 A1	2/1983	European Pat. Off. .
0 087 995 B1	2/1983	European Pat. Off. .
0 518 475 A1	12/1992	European Pat. Off. .
0 566 784 A1	10/1993	Japan .
WO 94/23092	10/1994	WIPO .

OTHER PUBLICATIONS

Wayne F. Patton, et al., "Tris–Tricine and Tris–Borate Buffer Systems Provide Better Estimates of Human Mesothelial Cell Intermediate Filament Protein Molecular Weights than the Standard Tris–Glycine System," Analytical Biochemistry, vol. 197, pp. 25–33 (Aug. 15, 1991).

Lide, ed. (CRC Handbook of Chemistry and Physiscs, 77th ed., 1996–1997, pp. 7–12), month unavailable 1996.

Allen, Robert C. and Doktycz, Mitchel, J., "Discontinuous electrophoresis revisited: A review of the process", *Applied and Theoretical Electrophoresis*, vol. 6, (1996), pp. 1–9 month unavailable.

Bhat, Suraj P., "DNA Sequencing on Minigels: An Alternative Technique for Routine Analysis", *Academic Press, Inc.*, (1993), pp. 560–562.

Carninci, Piero et al., "A discontinuous buffer system increasing resolution and reproducibility in DNA sequencing on high voltage horizontal ultrathin–layer electrophoresis", *Electrophoresis*, vol. 16, (1995), pp. 1836–1845 month unavailable.

Peacock, Andrew C. and Dingman, C. Wesley, "Molecular Weight Estimation and Separation of Ribonucleic Acid by Electrophoresis in Agarose–Acrylamide Composite Gels", *Biochemistry*, vol. 7, No. 2, (1968) pp. 668–674 month unavailable.

Raymond, Samuel and Weintraub, Lewis, "Acrylamide Gel as a Supporting Medium for Zone Electrophoresis", *Science*, vol. 130, (1959) pp. 711–712 month unavailable.

Swerdlow, Harold et al., "Reloading and Stability of Polyacrylamide Slab Gels for Automated DNA Sequencing", *BioTechniques*, vol. 16, No. 4, (1994), pp. 684–693 month unavailable.

Swerdlow, Harold et al., "Stability of capillary gels for automated sequencing of DNA", *Electrophoresis*, vol. 13, (1992), pp. 475–483 month unavailable.

"The Protein Society", Protein Science Program & Abstracts, vol. 5, Suppl. 1, (1996), 478–M month unavailable.

Andrews, Anthony T., "Electrophoresis, Theory, Techniques, and Biochemical and Clinical Applications", *Oxford Science Publications*, Second Edition, (1986), pp. 79–92 month unavailable.

Chrambach, Andreas and Jovin, Thomas M., "Selected buffer systems for moving boundary electrophoresis on gels at various pH values, presented in a simplified manner", *Electrophoresis*, (1983), vol. 4, pp. 190–204 month unavailable.

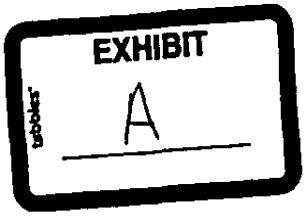
(List continued on next page.)

Primary Examiner—William H. Beisner
Assistant Examiner—Alex Noguerda
Attorney, Agent, or Firm—Fish & Neave; Edward J. DeFranco; James Trosino

[57] **ABSTRACT**

A gel and buffer system for gel electrophoresis wherein separation occurs at neutral pH.

20 Claims, No Drawings



OTHER PUBLICATIONS

Christy, Kenneth G., Jr., LaTart, David B., and Osterhoudt, Hans W., "Modifications for SDS–Page of Proteins", *Bio-Techniques*, vol. 7, No. 7, (1989), pp. 692–693 month unavailable.

Fritz, Jeffery, D., Swartz, Darl R., and Greaser, Marion L., "Factors Affecting Polyacrylamide Gel Electrophoresis and Electroblotting of High–Molecular–Weight Myofibrillar Proteins", *Analytical Biochemistry*, vol. 180, (1989), pp. 205–210 month unavailable.

Hames, B.D. and Rickwood, D., "Gel Electrophoresis of Proteins, A Practical Approach", *The IRL Press at Oxford University Press*, Second Edition, (1990), pp. 1–50 month unavailable.

Jovin, Thomas M., "Multiphasic Zone Electrophoresis. I, II & III Steady–State Moving–Boundary Systems Formed by Different Electrolyte Combinations", *Biochemistry*, vol. 12, No. 5, (1973) pp. 871–898, month unavailable.

Jovin, Thomas M., "Multiphasic Zone Electrophoresis. IV. Design and Analysis of Discontinuous Buffer Systems with a Digital Computer", *Annals New York Academy of Science, Jovin: Computer Design of Buffer Systems*, (1973), pp. 477–496 month unavailable.

Kyte, Jack and Rodriguez, Henry, "A Discontinuous Electrophoretic System for Separating Peptides on Polyacrylamide Gels", *Academic Press, Inc.*, (1983), pp. 515–522 month unavailable.

Lane, Leslie C., "A Simple Method for Stabilizing Protein–Sulfhydryl Groups during SDS–Gel Electrophoresis", *Analytical Biochemistry*, vol. 86, (1978), pp. 655–664 month unavailable.

Martin de Llano, J. Javier and Gavilanes, Jose G., "Increased electrophoretic mobility of sodium sulfite–treated jack bean urease", *Electrophoresis*, vol. 13, (1992), pp. 300–304 month unavailable.

Moos, Malcolm, Jr., Nguyen, Nga Yen, and Liu, Teh–Yung, "Reproducible High Yield Sequencing of Proteins Electrophoretically Separated and Transferred to an Inert Support", *The Journal of Biological Chemistry*, vol. 263, No. 13, (1988), pp. 6005–6008 month unavailable.

Wiltfang, Jens, Arold, Norbert, and Nuebogg, Volker, "A new multiphasic buffer system for sodium dodecly sulfate–polyacrylamide gel electrophoresis of proteins and peptides with molecular masses 100 000–1000, and their detection with picomolar sensitivity", *Electrophoresis*, vol. 12, (1991), pp. 352–366 month unavailable.

"Electrophoresis, The NOVEX System: The Fast, Easy Way To Your Answer!", NOVEX Brochure (1992) month unavailable.

"Technically Speaking . . . , NOVEX Pre-mixed Buffers, Fast, Easy, Reproducible Electrophoresis Buffers", NOVEX Brochure (1993) month unavailable.

"Migration Tables" and "Buffer Selection Guide", NOVEX Brochure, (1991).

SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL

This application is a continuation in part of application Ser. No. 08/221,939, filed Mar. 31, 1994, now U.S. Pat. No. 5,578,180.

This invention relates to techniques for gel electrophoresis. More particularly this invention relates to a novel system for gel electrophoresis at approximately neutral pH.

BACKGROUND OF THE INVENTION

Gel electrophoresis is a common procedure for the separation of biological molecules, such as deoxyribonucleic acid (DNA), ribonucleic acid (RNA), polypeptides and proteins. In gel electrophoresis, the molecules are separated into bands according to the rate at which an imposed electric field causes them to migrate through a filtering gel.

The basic apparatus used in this technique consists of a gel enclosed in a glass tube or sandwiched as a slab between glass or plastic plates. The gel has an open molecular network structure, defining pores which are saturated with an electrically conductive buffered solution of a salt. These pores through the gel are large enough to admit passage of the migrating macromolecules.

The gel is placed in a chamber in contact with buffer solutions which make electrical contact between the gel and the cathode or anode of an electrical power supply. A sample containing the macromolecules and a tracking dye is placed on top of the gel. An electric potential is applied to the gel causing the sample macromolecules and tracking dye to migrate toward the bottom of the gel. The electrophoresis is halted just before the tracking dye reaches the end of the gel. The locations of the bands of separated macromolecules are then determined. By comparing the distance moved by particular bands in comparison to the tracking dye and macromolecules of known mobility, the mobility of other macromolecules can be determined. The size of the macromolecule can then be calculated.

The rate of migration of macromolecules through the gel depends upon three principle factors: the porosity of the gel; the size and shape of the macromolecule; and the charge density of the macromolecule. It is critical to an effective electrophoresis system that these three factors be precisely controlled and reproducible from gel to gel and from sample to sample. However, maintaining uniformity between gels is difficult because each of these factors is sensitive to many variables in the chemistry of the gel system.

Polyacrylamide gels are commonly used for electrophoresis. Polyacrylamide gel electrophoresis or PAGE is popular because the gels are optically transparent, electrically neutral and can be made with a range of pore sizes. The porosity of a polyacrylamide gel is in part defined by the total percentage of acrylamide monomer plus crosslinker monomer ("%T") it contains. The greater the concentration, the less space there is between strands of the polyacrylamide matrix and hence the smaller the pores through the gel. An 8% polyacrylamide gel has larger pores than a 12% polyacrylamide gel. An 8% polyacrylamide gel consequently permits faster migration of macromolecules with a given shape, size and charge density. When smaller macromolecules are to be separated, it is generally preferable to use a gel with a smaller pore size such as a 20% gel. Conversely for separation of larger macromolecules, a gel with a larger pore size is often used, such as an 8% gel.

Pore size is also dependent upon the amount of crosslinker used to polymerize the gel. At any given total monomer concentration, the minimum pore size for a polyacrylamide gel is obtained when the ratio of total monomer to crosslinker is about 20:1, (the usual expression for this ratio would be "5% C").

Several factors may cause undesirable variation in the pore size of gels. Pore size can be increased by incomplete gel polymerization during manufacture. Hydrolysis of the polyacrylamide after polymerization can create fixed negative charges and break down the crosslinks in the gel, which will degrade the separation and increase the pore size. An ideal gel system should have a reproducible pore size and no fixed charge (or at least a constant amount) and should be resistant to change in chemical characteristics or the pore size due to hydrolysis.

The size of the macromolecule varies between different macromolecules; the smaller and more compact the macromolecule the easier it will be for the macromolecule to move through the pores of a given gel. Given a constant charge density, the rate of migration of a macromolecule is inversely proportional to the logarithm of its size.

For accurate and reproducible electrophoresis, a given type of macromolecule should preferably take on a single form in the gel. One difficulty with maintaining uniformity of the shape of proteins during gel electrophoreses is that disulfide bonds can be formed by oxidation of pairs of cysteine amino acids. Different oxidized forms of the protein then have different shapes and, therefore, migrate through the gel run with slightly different mobilities (usually faster than a completely reduced protein, since the maximum stokes radius and minimum mobility should occur with a completely unfolded form). A heterogeneous mixture of forms leads to apparent band broadening. In order to prevent the formation of disulfide bonds, a reducing agent such as dithiothreitol (DTT) is usually added to the samples to be run. The shape of DNA and RNA macromolecules is dependent on temperature. In order to permit electrophoresis on temperature-dependent DNA and RNA molecules in their desired form, separations are done at a controlled temperature.

The charge density of the migrating molecule is the third factor affecting its rate of migration through the gel—the higher the charge density, the more force will be imposed by the electric field upon the macromolecule and the faster the migration rate subject to the limits of size and shape. In SDS-PAGE electrophoresis the charge density of the macromolecules is controlled by adding sodium dodecyl sulfate (SDS) to the system. SDS molecules associate with the macromolecules and impart a uniform charge density to them substantially negating the effects of any innate molecular charge. Unlike proteins, the native charge density of DNA and RNA is generally constant, due to the uniform occurrence of phosphate groups. Thus, charge density is not a significant problem in electrophoresis of DNA and RNA.

SDS PAGE gels are usually poured and run at basic pH. The most common PAGE buffer system employed for the separation of proteins is that developed by Ornstein (1) and modified for use with SDS by Laemmli (2). Laemmli, U. K. (1970) *Nature* 227, 680–686. The Laemmli buffer system consists of 0.375M (tris (hydroxy methyl) amino-methane (Tris), titrated to pH 8.8. with HCl, in the separating gel. The stacking gel consists of 0.125M Tris, titrated to pH 6.8. The anode and cathode running buffers contain 0.024M Tris, 0.192M glycine, 0.1% SDS. An alternative buffer system is disclosed by Schaegger and von Jagow. Schaegger, H. and von Jagow, G., *Anal. Biochem.* 1987, 166, 368–379. The stacking gel contains 0.75M Tris, titrated to pH 8.45 with

HCl. The separating gel contains 0.9M Tris, titrated to pH 8.45 with HCl. The cathode buffer contains 0.1M Tris, 0.1M N-tris(hydroxymethyl)methylglycine (tricine), 0.1% SDS. The anode buffer contains 0.2M Tris, titrated to pH 8.9 with HCl. For both of these systems Tris is the "common ion" which is present in the gel and in the anode and cathode buffers.

In the Laemmli system, the pH of the trailing phase in the stacking gel is about 8.9. In the separating gel, the trailing phase pH is about 9.7. At this pH, primary amino groups of proteins react readily with unpolymerized acrylamide, thiol groups are more subject to oxidation to disulfides, or reaction with unpolymerized polyacrylamide, than at neutral pH and acrylamide itself is subject to hydrolysis.

The shape of the DNA and RNA macromolecules is also dependent on a fourth important factor, temperature. The temperature-dependent shape of DNA and RNA is caused by the interaction of two macromolecules containing complementary sequences and the interaction of complementary sequences in a single macromolecule. Some techniques require that the DNA remain in its double-stranded form. Typically, such separations are done in (Tris borate ethylene diamine tetra-acetic acid) (TBE) buffer, consisting of 0.09M Tris, 0.09M boric acid, and 0.002M EDTA (ethylene diamine tetra-acetic acid) on either polyacrylamide or agarose gels. In general, these separations are done at lower temperatures to maintain the double-stranded structure. In the absence of denaturants, DNA's and RNA's structure is fairly stable and not significantly affected by temperature.

In other techniques, dissociation of the two DNA strands (known as "melting") is utilized to effect the separation. Such methods require careful temperature control in order to produce a consistent separation. One method, non-isotopic single-strand conformational polymorphism ("Cold SSCP"), utilizes a dissociative sample buffer with heat to melt the strands, a TBE buffer, and a polyacrylamide gel. In Cold SSCP, temperatures of 4 to 35° C. are used to allow variable-conformation renaturation to occur between mutant strands, and temperature changes of only a few degrees can significantly alter the number of mutants seen. See Hongyo, et al, *Nucleic Acids Research*, 21, 3637 (1993). Another method, employed in DNA sequence analysis, typically utilizes TBE buffers containing 6 to 8M urea and/or 2 to 12M formamide, and elevated temperatures. It is important that the temperature remain high enough—typically 45 to 55° C.—to maintain fully melted DNA or RNA. Gels are usually polyacrylamide and sometimes substituted acrylamide polymers. For example, certain alkyl-substituted polyacrylamide gels are described in Shoor et al, U.S. Pat. No. 5,055,517.

These DNA and RNA separation methods are characterized by the use of continuous buffer systems, which use the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber, and the cathode chamber. These buffers usually are comprised of Tris and boric acid with EDTA added to inhibit hydrolytic enzyme activity. The TBE buffer system typically does not provide good stability when used in pre-cast gels, made and stored for periods of weeks at 4° C. The polymer tends to break down, generating a fixed charge which leads to distortion particularly at the cathode end of the gel where resolution is especially important. Urea also tends to break down under alkaline pH at 4° C. When large concentrations of urea are present, the ionic breakdown products can be present at a large enough concentration to disrupt the separation and cause loss of resolution.

Other buffer systems for DNA and RNA separations employ Tris/acetate, Tris/phosphate, and Tris/glycylglycine. While these buffer systems may be formulated near pH 7, the pK_a of Tris causes them to shift to an alkaline pH during electrophoresis especially near the cathode. The applicants have found that the polyacrylamide and urea tend to break down during electrophoresis for DNA sequencing due to the high temperatures (50° C.) employed for several hour runs when Tris is used as the buffering base. This breakdown leads to higher current and lower resolution than might be obtained with a neutral pH buffer system, so that the DNA sequence read length is reduced and read errors are increased.

The need for uniformity and predictability is magnified in precast electrophoresis gels which are manufactured by an outside vendor and then shipped to the laboratory where the electrophoresis will be performed. Precast gels must control the properties discussed above and they must be able to maintain this control throughout shipping and storage. The shelf life of many precast gels is limited by the potential for hydrolysis of acrylamide and/or buffer constitution during storage at the high pH of the gel buffer.

It is a disadvantage of a high pH gel that the polyacrylamide gel is subject to degradation by hydrolysis and has a limited shelf-life.

It is a further disadvantage of a high pH gel that proteins react readily with unpolymerized acrylamide which may interfere with subsequent analysis of the protein such as peptide sequencing.

It is a still further disadvantage of a high pH gel that thiol groups are subject to oxidation to disulfides causing a decreased resolution of separated macromolecules.

It is a further disadvantage of a high pH gel that buffer constituents such as urea break down readily.

SUMMARY OF THE INVENTION

It is an object of this invention to produce a neutral gel system that reduces protein reaction with unpolymerized acrylamide thereby enhancing yield and resolution.

It is a further object of this invention to produce a neutral gel system that prevents formation of disulfides from free thiol groups thereby enhancing yield and resolution.

It is also an object of this invention to produce a neutral gel system that reduces degradation of the polyacrylamide gel by hydrolysis thereby increasing the stability of a gel during electrophoresis and the useful shelf-life of a precast gel, and better resolution.

It is also an object of this invention to produce a neutral gel system that reduces breakdown of buffer constituents, such as urea.

In accordance with this invention, applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Applicants also describe a gel and buffer system wherein storage of the gel and subsequent electrophoresis of macromolecules (such as DNA, RNA, polypeptides and proteins) occurs at neutral pH. The above and other objects and advantages of the present invention will be apparent upon consideration of the following detailed description.

DETAILED DESCRIPTION OF THE INVENTION

Applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Advantageously, at this neutral pH, primary amino groups of proteins react less readily with unpolymerized acrylamide because protonation of protein amino

groups greatly reduces their reactivity to acrylamide or other related blocking agents. Furthermore, at this neutral pH, thiol groups are less subject to oxidation than at higher pH and polyacrylamide itself is less subject to hydrolysis.

The result is a gel system with improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers without reducing agents and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance. An additional benefit is that a single gel recipe, using the same buffer for the stacking and separating gels, can be used with two different running buffers to give two separation systems. Using this feature, an 8% gel, for example, can cover a protein separation range of 2 to 200 kDa.

In one embodiment of this invention a polyacrylamide gel of between about 3% and about 25% (% T) acrylamide is polymerized using from about 1% to about 6% crosslinker (% C) using a gel buffer comprising a primary organic amine or substituted amine with a pK_a near neutrality, titrated with approximately half as much HCl (on a molar basis), so that the pH of the buffer is approximately neutral. In a preferred embodiment the gel is polymerized using from about 2% to about 5% crosslinker (% C) using a gel buffer comprising [bis-(2-hydroxyethyl) iminotris (hydroxymethyl) methane] (Bis-Tris) titrated with HCl. Different separation characteristics can be obtained by running the gel with either a (3-(N-morpholino) propanesulfonic acid) (MOPS) or (2-(N-morpholino) ethanesulfonic acid) (MES), buffer. 2 mM to 10 mM thioglycolic acid (TGA) or 2 mM to 10 mM sodium bisulfite is added to the running buffer to maintain a reducing environment in the gel during electrophoresis.

Applicants also describe another gel and buffer system for separation of macromolecules (including DNA, RNA, polypeptides and proteins) wherein separation occurs at neutral pH. This gel and buffer system may be a discontinuous or continuous buffer system, but is particularly useful in a continuous system. A continuous buffer system is one using the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber and the cathode chamber. This gel and buffer system permits higher resolution during electrophoresis when alkaline-labile compounds such as polyacrylamide and urea are present. This gel and buffer system also permits higher resolution when elevated temperatures are used. Advantageously, at this neutral pH, urea is less subject to hydrolysis. Furthermore, polyacrylamide itself is less subject to hydrolysis.

This gel and buffer system also possesses improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance.

In an embodiment of this gel and buffer system an electrophoresis gel is uniformly saturated with a gel buffer solution comprising a primary organic amine or substituted amine with a pK_a near neutrality, titrated with approximately an equimolar amount of acid or zwitterionic compound, so that the pH of the buffer is between about pH 6 and pH 8, preferably between about pH 6.5 to pH 7.5, and most preferably 6.5 to 7.0. The electrophoresis gel may be any agarose or polyacrylamide gel. Preferably, the electrophoresis gel comprises between 3% and 25% (% T) acrylamide polymerized using from about 1% to about 6% cross linker (% C). More preferably, this polyacrylamide gel is polymerized using from about 2% to about 5% crosslinker (% C). Preferably, the amine comprises Bis-Tris or N-(2-hydroxyethyl) morpholine, and most preferably, Bis-Tris. Suitable acids and zwitterionic compounds are hydrochloric acid, tricine, acetic acid, piperazine-N,N'-2-ethanesulfonic acid, 3-(N-morpholino)-propanesulfonic acid, 2-(N-morpholino)-ethanesulfonic acid, N-(2-acetamido)-2-aminoethanesulfonic acid, 2-(N-morpholino)-2-hydroxypropanesulfonic acid, N-tris-(hydroxymethyl)-2-ethanesulfonic acid, N-2-hydroxyethyl-piperazine-N-2-ethanesulfonic acid, N,N-bis-(hydroxyethyl)-2-aminoethanesulfonic acid, and 3-(N-tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid. Tricine, 2-(N-morpholino)-ethanesulfonic acid, and piperazine-N, N'-2-ethanesulfonic acid are preferred for use in the buffer for a continuous gel and buffer system for separation of DNA and RNA because the resulting system has separation characteristics similar to the commonly used TBE gel systems. Tricine is most preferred for that use. Preferably, the gel buffer comprises Bis-Tris titrated with tricine.

In a gel and buffer system, current increases and migration rates decline as the performance of the gels decline. The increase in current has been attributed to alkaline-catalyzed hydrolysis of urea present at 36% to 42% concentration. Any breakdown in a neutral substance present at a large concentration, which produces a charged species will tend to disrupt the electrophoresis. This disruption arises from the extra current produced, which in turn increases joule heating without aiding the separation. In addition, a discontinuity arises from the anionic and cationic hydrolysis products forming in the gel that are not present in the cathode and anode buffers. Hydrolysis of gel buffer species or additives takes place independently from the gel matrix composition. The decrease in migration rate may be attributed to higher fixed charge in the gel caused by alkaline-catalyzed hydrolysis of the gel's polyacrylamide. The fixed charge leads to significant counter-flow of water, which can retard a macromolecule's migration rate. It has been found that problems of gel instability producing lower resolution, increased current, decreased migration rates can be solved with gels buffered near neutrality and with buffer substances having a pK_a near neutrality. Such buffering systems improve the performance of fresh or pre-cast polyacrylamide gels, and fresh or pre-cast gels containing alkaline-labile materials, such as urea or formamide, even when the gels are made with base-stable polymers.

The inventors also have discovered the value of using different buffer substances in the cathode, gel, and anode buffers. A group of substitutions relating to cost and throughput have been discovered. The anionic substance used in the gel or the cathode buffer need not be present in the anode buffer since the anions do not migrate out of the anode buffer. In fact, the use of chloride or other strong acids in the anode buffer serves to increase the conductance of the buffer, thereby increasing the net voltage drop across the gel and decreasing run times. Such acids are also typically much less expensive as compared to those employed in the cathode buffer. Similarly, the base used to adjust the pH of the cathode buffer need not be the same as that used in the gel. At a neutral pH, sodium hydroxide, Tris, and other organic bases with a basic pK_a have a higher conductance and often lower cost than Bis-Tris or other bases with a pK_a near neutrality. Using sodium or Tris salts in the cathode buffer will also decrease the gel run times. Often, the anode and

cathode buffers are used at a higher concentration than in the gel, further increasing their conductance and decreasing gel run times. Thus, using different, more conductive anode and cathode buffer species than in the gel buffer increases throughput and decreases costs.

It was also found that Tris or Bis-Tris may be used in the anode buffer with no visible effect on the separation quality. Because of its higher pK_a, Tris gradually infiltrates the anode end of the gel increasing that region's conductance, causing the voltage drop to fall locally. Thus, the macromolecules near the anode slow down and the separation compresses, while the macromolecules near the cathode experience a higher voltage drop increasing their migration and relative separation. This effect of Tris actually improves the resolution of macromolecules at the cathode end of the gel where it is most needed. Tris is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris and can improve read lengths.

The preferred embodiment of this invention uses Tris chloride in the anode buffer, the sodium or Tris salt of the acid or zwitterionic compound in the cathode buffer, and Bis-Tris as the gel buffer amine. For protein and polypeptide separations, the most preferred cathode buffers are sodium or Tris salts of MOPS and MES, combined with a Bis-Tris chloride gel buffer. For DNA and RNA separations, the most preferred cathode buffers are sodium or Tris salts of tricine, combined with a Bis-Tris tricine EDTA running buffer. When the buffer chambers are small, the most preferred molar concentrations of the cathode and anode buffers are five times that present in the gel buffer. These buffer systems provide the benefits of a neutral pH gel during both storage and running, the least cost, and the fastest run times.

These and other embodiments can be understood by reference to the following illustrative and comparative examples.

EXAMPLES

Tris, Bis-Tris, MES, tricine, MOPS and piperazine-N,N'-2-ethanesulfonic acid (PIPES) were purchased from Sigma (St. Louis, Mo.) or Research Organics (Cleveland, Ohio). Thioglycolic acid (TGA), dithiothreitol (DTT) and beta-mercaptoethanol (BME) were from Sigma. All other chemicals were reagent, "ultra pure" or "electrophoresis grade" from standard sources.

In Example 1 through 6, gels were cast in 1 mm thickness mini-gel cassettes from Novex (San Diego Calif.) and run in an Xcell minicell. The Bis-Tris separating gel and stacking gels were prepared from a 30%T/2.5%C acrylamide/BIS stock solution and a 7× Bis-Tris stock solution (2.5M Bis-Tris, 1.5M HCl, pH 6.5). To prepare the separating gel, the stock solutions were blended with ultra pure water to a final concentration 8%T, 0.357M Bis-Tris, to which was added 0.2 ul/ml temed. After degassing, 2.0 ul/ml of a 10% solution of ammonium persulfate (APS) was added, the gel was immediately poured into the cassette then overlaid with water. Polymerization was allowed to proceed for at least 30 minutes at room temperature (RT), the water was removed and a 4% stacking gel applied. The stacking gel was prepared in the same fashion as the separating gel, except that the final concentration obtained was 4%T, N,N,N',N'-tetra-methyl-ethylene-diamine (TEMED) concentration was increased to 0.4 ul/ml and the APS solution increased to 5.0 ul/ml. MOPS running buffer consisted of 50 mM MOPS, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. MES running buffer consisted of 50 mM MES, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. Sample buffer (2×) consisted of 0.25M Bis-Tris, 0.15M HCl, 10% (w/v) Glycerol, 2% SDS, 1 mM EDTA, 0.03% Serva Blue G, and 200 mM DTT. Samples containing a set of protein standards were heated for 15 min at 70 degrees before application. Bovine serum albumin (BSA), chicken egg ovalbumin, alkylated insulin A and B chain, soybean trypsin inhibitor, and bovine erythrocyte carbonic anhydrase were included in the standard. Sample volume was 5 ul in all cases.

Example 1

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the absence of a reducing agent. The resulting separation pattern was very similar to that obtained on an 8% Tris/glycine gel (Laemmli), with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The BSA band was somewhat diffuse and shifted toward the anode. The Ovalbumin band was also somewhat diffuse.

Example 2

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of TGA in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without TGA.

Example 3

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of sodium bisulfite in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without sodium bisulfite.

Example 4

The protein standards were separated on an 8% Bis-Tris/Cl gel with MES running buffer in the absence of a reducing agent. The protein separation was very similar to that obtained from an 12% Tris/tricine (Schaegger) gel. All proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). When the gel is run without TGA, soybean trypsin inhibitor had a more prominent doublet.

Example 5

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of TGA in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Example 6

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of

sodium bisulfite in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Although MES and MOPS were selected as desirable running buffers for protein separation because the resulting system has separation characteristics similar to the commonly used Laemmli and Schaegger gel systems, it was found that a range of buffers are suitable for use in this system. Among the additional buffers giving good results were ([N-(2-acetamido)]-2-aminoethanesulfonic acid) (ACES), (2-[N-morpholino]-2-hydroxypropanesulfonic acid) (MOPSO), (N-Tris-(hydroxymethyl)-2-ethanesulfonic acid) (TES), (N,N-bis-(hydroxyethyl)-2-aminoethanesulfonic acid) (BES), (N-2-hydroxyethylpiperazine-N-2-ethanesulfonic acid) (HEPES), and (3-(N-Tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid).

All the proteins that exhibit some band broadening and/or mobility shifts when run in the absence of TGA or sodium bisulfite, have in common a composition that includes multiple cysteines (BSA, for instance, has 35 cysteines). On the other hand carbonic anhydrase, which always runs cleanly, has no cysteines. Moreover, if the reduced proteins are alkylated before running, they run as sharp homogeneous bands even in the absence of a reducing agent.

Cysteine-containing proteins appear to give generally sharper bands in the Laemmli system than the neutral system, when both are run with 100 mM mercaptoethanol or DTT in the sample buffer but without TGA in the running buffer. Since thiol oxidation is more favored as the pH increases, it would be expected that the higher pH of the Laemmli system would cause oxidation of disulfide to be at least as pronounced as it is in the neutral pH system. However, DTT and similar "neutral" thiol reducing agents are weak acids (with pK_a's around pH 8–9). Thus, at basic pH, these reducing agents migrate into the gel and, if present at sufficient concentration, provide some protection against oxidation of sulfhydryls. At a neutral separating pH, DTT from the sample buffer is in an uncharged form and will remain behind in the sample well. Thus, no reducing agent migrates into the gel.

To maintain proteins in a reduced form during electrophoresis at neutral pH, it was found advantageous to use a reducing agent that would migrate into the gel at neutral pH. Sodium bisulfite (2–10 mM) was found to maintain a reducing environment in the gel during electrophoresis. Fully reduced TGA (or similar negatively charged thiols) give similar results at comparable concentrations. However, partially oxidized TGA will promote partial oxidation of protein thiols. Because reduction (oxidation) of protein thiols will take place via disulfide interchange, the ratio of reduced to oxidized thiols in the protein will substantially reflect the ratio of reduced to oxidized thiols in the TGA. Conversely, sulfite oxidizes to sulfate, which does not participate in redox reactions under conditions found in the gel. Therefore, regardless of the sulfite/sulfate ratio in a partially oxidized preparation of sulfite, as long as sufficient sulfite remains, proteins will be protected against thiol oxidation.

It was also found that Tris could be substituted for Bis-Tris in the running buffer with no visible effect on the separation quality. Bis-Tris may be preferred where the protein will be intentionally modified post-separation. Bis-Tris is a tertiary amine and will not interfere with the protein modifying agents which react through primary amines. Tris, however, is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris.

Example 7

A 14.7% T/5% C TBE urea gel was made in the following manner. To prepare the separating gel solution, a 30% acrylamide/1.6% bis-acrylamide stock solution (47.5 ml), and a 5× gel buffer stock solution containing 0.45M Tris, 0.45M boric acid, and 0.01M EDTA, pH 8.18 (20 ml) were mixed with urea (36 g), TEMED (20 ul), and enough water was added to make 100 ml. The final solution pH was 8.87. It was degassed, a 10% ammonium persulfate solution ("10 % APS") (12.8 ul) was added to 6.4 ml, and poured into a 1 mm thick mini-gel cassette from Novex (San Diego, Calif.). A comb-forming gel solution was made similarly, with the following differences: acrylamide/bis solution (12.7 ml), TEMED (50 ul), and no urea; to 1.0 ml of this solution was added 10% APS (0.1Ml) and it was immediately poured on top of the separating gel solution. A 1 mm 10-well comb (Novex) was added, and the gels were allowed to polymerize for at least 30 minutes at room temperature. They were then run after storage in sealed pouches with 1× gel buffer containing 7M at different temperatures.

The gels were run fresh or after storage at either 4° C. or 35° C. Samples employed were a 10b oligo DNA standard (BRL, Bethesda, Md.) or an 18-mer custom-synthesized DNA fragment (Synthetic Genetics, San Diego, Calif.). Gels were run in an X-Cell mini-cell (Novex) at 180 volts for 80 minutes, using 1× gel buffer in both the anode and cathode chambers. Finally, the bands were visualized by treating with Stains-All solution (Sigma) for 15 minutes then destaining in 20% methanol for 10 minutes.

Compared to fresh gels, the gels stored at 4° C. showed a gradual loss of band sharpness and an increase in current during the electrophoresis. The loss of sharpness leads to less resolution between bands. After 2 weeks at 4° C., the band width had doubled as compared to fresh gel bands. When stored at 35° C. for 1 week, the gels ran with higher current but the dye front only migrated 80% as far in 80 minutes. The gel itself retained the stain, and the bands were fuzzy and indistinct. After three weeks, no bands could be seen and the gels were very fragile.

Example 8

Gels were prepared, stored, and run as described in Example 7, except that the 5× gel buffer was composed of 0.45M Bis-Tris, 0.45M tricine, and 0.01M EDTA pH 7.27, the final gel solution pH was 7.70, and the running buffer was 0.05M Tris, 0.05M tricine, 0.001M EDTA. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to 3 weeks at 35° C. or for several months at 4° C.

Example 9

Gels were prepared, stored, and run as described in Example 7, except that the 5× gel buffer was composed of 0.125M N-(2-hydroxyethyl) morpholine (HEM), 0.083M acetic acid, and 0.002M EDTA pH 7.0, and the final gel solution pH was 7.21. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to three weeks at 35° C. or for several months at 4° C. However, the gels turned yellow on storage at 35° C.

Example 10

Mini-DNA sequencing gels were prepared from the same separating gel solution as described in Example 7, except

that only 23.3 ml of acrylamide/bis solution was employed, the urea was increased to 42 g, and the TEMED was increased to 50 ul. It was used without degassing by adding 10% APS (50 ul) to 10 ml of the solution, and pouring between 11 cm wide by 22 cm long thick glass plates with 0.25 mm spacers. The gels were allowed to polymerize for 60 minutes at room temperature, then run the same day.

Samples employed were an M-13 DNA sequencing reaction prepared with S^{35}-label using a USB Sequenase kit, version 2, (United States Biochemicals, Cleveland, Ohio). They were run in a custom-made DNA sequencing chamber at 15 watts (circa 50° C.). Finally, the bands were visualized by autoradiography. The gels had a read length of 120 bases with a 5% error rate (95% accuracy).

Example 11

Gels were prepared and run as in Example 10, except that the 5× gel buffer was composed of 0.5M Bis-Tris, 0.84M tricine, and 0.01M EDTA pH 7.2 and the final gel solution pH was 7.50. The gels had a read length of 137 bases with a 1.5% error rate (98.5% accuracy).

Example 12

The separating gel solution was prepared as in Example 7, except that a SoaneGel SQ solution (a solution of substituted acrylamide and substituted bis-acrylamide cross-linkers, available from Soane Biosciences Inc., Hayward, Calif.) was used for the polymer at 6%T, and the TEMED was increased to 88 ul. After initiation of the gel solution (40 ml) with 10% APS (200 ul), the gels were poured in plates with 0.35 mm spacers for an ABI Model 377 DNA Sequencer (Applied Biosystems Division of Perkin Elmer Corp., Foster City, Calif.), and allowed to polymerize at room temperature for 2 hours. The gels were loaded with a pGEM sequencing reaction and run with 1× TBE buffer at 30 V/cm, generating 55° C. They had a read length of 815 bases; at 550 bases the error rate was 1.5% (98.5% accuracy).

Example 13

Gels were prepared and run as in Example 12, except that the 5× gel buffer was composed of 0.5M Bis-Tris, 0.84M tricine, and 0.01M EDTA pH 7.2, and the final gel solution pH was 7.5. The gels were run with 1× gel buffer at 30 V/cm, generating 55° C., and had a read length of 866 bases; at 550 bases the error rate was 1.1% (98.9% accuracy).

While the invention has been explained in relation to its preferred embodiments, it is to be understood that various modifications thereof will become apparent to those skilled in the art. The foregoing disclosure is not intended or to be construed to limit the present invention, or to otherwise exclude any such other embodiments, adaptions, variations and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

We claim:

1. Apparatus for use in a discontinuous buffer gel electrophoresis system, the apparatus comprising:

a slab of precast electrophoresis gel adapted for insertion in an electrophoresis container, the gel uniformly saturated with a gel buffer comprising a primary organic amine or substituted amine with a PKa near neutrality, titrated with hydrochloric acid or acetic acid, to a pH between pH 5.5 and pH 7.5.

2. The apparatus of claim 1, wherein the amine is Bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane.

3. The apparatus of claim 1, wherein the electrophoresis gel is a polyacrylamide gel.

4. The apparatus of claim 1, wherein the acid is hydrochloric acid.

5. The apparatus of claim 4, wherein the electrophoresis gel is a polyacrylamide gel.

6. The apparatus of claim 1, wherein the acid is acetic acid.

7. The apparatus of claim 6, wherein the electrophoresis gel is a polyacrylamide gel.

8. The apparatus of claim 1, wherein the slab or precast gel is further adapted for fluid communication with a cathode buffer.

9. The apparatus of claim 8, wherein the cathode buffer comprises sulfite.

10. The apparatus of claim 8, wherein the cathode buffer comprises a thiol.

11. The apparatus of claim 8, wherein the cathode buffer comprises thioglycolic acid.

12. Apparatus for use in a continuous buffer gel electrophoresis system, the apparatus comprising:

a slab of precast electrophoresis gel adapted for insertion in an electrophoresis container, the gel uniformly saturated with a gel buffer comprising a primary organic amine or substituted amine with a pK_a near neutrality, titrated with a zwitterionic compound selected from the group consisting of N-tris(hydroxymethyl) methylglycine, piperazine-N, N'-2-ethanesulfonic acid, 3-(N-morpholino)-propanesulfonic acid, 2-(N-morpholino)-ethanesulfonic acid, N-(2-acetamido)-2-aminoethanesulfonic acid, 2-(N-morpholino)-2-hydroxypropanesulfonic acid, N-tris-(hydroxymethyl)-2-ethanesulfonic acid, N-2-hydroxyethyl-piperazine-N-2-ethanesulfonic acid, N,N-bis-(hydroxyethyl)-2-aminoethanesulfonic acid, and 3-(N-tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid, to a pH between pH 5.5 and pH 7.5.

13. The apparatus of claim 12, wherein the electrophoresis gel is a polyacrylamide gel.

14. The apparatus of claim 12, wherein the zwitterionic compound is N-tris(hydroxymethyl)methylglycine.

15. The apparatus of claim 12, wherein the amine is Bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane.

16. The apparatus of claim 12, wherein the gel buffer comprises a compound selected from the group consisting of urea and formamide.

17. The apparatus of claim 12, wherein the slab or precast gel is further adapted for fluid communication with a cathode buffer.

18. The apparatus of claim 17, wherein the cathode buffer comprises tris (hydroxy methyl) amino-methane.

19. The apparatus of claim 12, wherein the slab or precast gel is further adapted for fluid communication with an anode buffer.

20. The apparatus of claim 19, wherein the anode buffer comprises tris (hydroxy methyl) amino-methane.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,922,185

DATED : July 13, 1999

INVENTOR(S) : Timothy V. Updyke, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2, line 60, delete "(" (first occurrence).

Column 3, line 23, delete "EDTA (".

Column 3, line 24, change "acid)" to --acid (EDTA)--.

Column 5, line 27, delete "[".

Column 5, line 27, delete "]".

Column 5, line 30, change "(3" to --3--.

Column 5, line 30, change "acid)" to --acid--.

Column 5, line 30, change "(2" to --2--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,922,185

DATED : July 13, 1999

INVENTOR(S) : Timothy V. Updyke, et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 5, line 31, change "acid)" to --acid--.

Column 7, line 48, change "Xcell" to --X-Cell--.

Column 7, line 54, change "temed" to –N, N, N', N'- tetra-methyl-ethylene-diamine (TEMED)--.

Column 11, line 12, change "circa" to --about--.

Signed and Sealed this

Twenty-third Day of November, 1999

Attest:

Q. TODD DICKINSON

Attesting Officer

Acting Commissioner of Patents and Trademarks

US006162338A

United States Patent [19]

Updyke et al.

[11] Patent Number: 6,162,338

[45] Date of Patent: *Dec. 19, 2000

[54] **SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL**

[75] Inventors: **Timothy V. Updyke**, Temecula; **Sheldon C. Engelhorn**, Cardiff-by-the-Sea, both of Calif.

[73] Assignee: **Novex**, Carlsbad, Calif.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/228,875**

[22] Filed: **Jan. 11, 1999**

Related U.S. Application Data

[63] Continuation of application No. 08/730,678, Oct. 11, 1996, Pat. No. 5,922,185, which is a continuation-in-part of application No. 08/221,939, Mar. 31, 1994, Pat. No. 5,578,180.

[51] **Int. Cl.**[7] **G01N 27/26**

[52] **U.S. Cl.** **204/468**; 204/606

[58] **Field of Search** 204/468, 469, 204/470, 456, 606

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,870,812	3/1975	Hayes, Jr. et al.	426/350
3,948,743	4/1976	Monthony et al.	204/180
4,139,440	2/1979	Chrambach et al.	204/180
4,209,373	6/1980	Bluestein et al.	204/180
4,481,094	11/1984	de Castro et al.	204/180
4,504,641	3/1985	Nochumson	526/238.2
4,542,200	9/1985	Nochumson	526/238.2
4,699,705	10/1987	Ogawa et al.	204/299
4,950,708	8/1990	Hochstrasser	524/728
5,275,708	1/1994	Akins et al.	204/182.8
5,370,777	12/1994	Guttman et al.	204/182.8
5,464,516	11/1995	Takeda et al.	204/182.9
5,578,180	11/1996	Engelhorn et al.	204/468

FOREIGN PATENT DOCUMENTS

0 087 995 A1	2/1983	European Pat. Off. .
0 087 995 B1	2/1983	European Pat. Off. .
0 566 784 A1	10/1993	European Pat. Off. .
94/23092	10/1994	WIPO .

OTHER PUBLICATIONS

Nakamura et al. Electrophoresis, pp. 10, 29–33, 1989 month unknown.

Wiltfang et al. "A new multiphasic buffer system for sodium dodecyl sulfate-polyacrylamide gel electrophoresis fo proteins and peptides with molecular masses 100 000–1000, and their detection with picomolar sensitivty" Electrophoresis, vol. 12, pp. 352–353, 1991 month unknown.

Jovin, "Multiphasic Zone Electrophoresis. IV. Design and Analysis of Discontinuous Buffer Systems with a Digital Computer", Annals New York Academy of Science, Jovin: Computer Design of Buffer Systems, pp. 477–496, 1973 month unknown.

Kyte et al. A Discontinous Electrophoretic System for Separating peptides on Polyacrylamide Gels, Academic Press, Inc. pp. 515–522 (1983) month unknown.

Hames et al., ed. "gel Electrophoresis of Proteins, A Practical Approach" The IRL press at Oxford University Press, econd edition, pp. 7–9, 1990 month unknown.

CAPLUS abstrat of Hoermann et al. "Dissociation of fibrinogen and fibrin peptide chains by partial cleavage of disulfide bonds", Hoppe-Seyler's Z. Physiol. Chem. 1973, 354(9), 1103–11 month unknown.

Samuel Raymond, et al., "Acrylamide Gel as a Supporting Medium for Zone Electrophoresis," *Science*, vol. 130, pp. 711–712, (1959). month unknown.

Andrew C. Peacock, et al., "Molecular Weight Estimation and Separation of Ribonucleic Acid by Electrophoresis in Agarose–Acrylamide Composite Gels," *Biochemistry*, vol. 7, No. 2, pp. 668–674, (1968). month unknown.

Thomas M. Jovin, "Multiphasic Zone Electrophoresis. I, II & III Steady-State Moving-Boundary Systems Formed by Different Electrolyte Combinations," *Biochemistry*, vol. 12, No. 5, pp. 871–898, (1973). month unknown.

Thomas M. Jovin, "Multiphasic Zone Electrophoresis. IV. Design and Analysis of Discontinuous Buffer Systems with a Digital Computer," *Annals New York Academy of Science, Jovin: Computer Design of Buffer Systems*, pp. 477–496, (1973). month unknown.

R. Ruechel, et al., Hoppe-Seyler's Z. Physiol. Chem., 356(8), pp. 1283–1288 (abstract), (1975). month unknown.

Leslie C. Lane, "A Simple Method for Stabilizing Protein-Sulfhydryl Groups during SDS-Gel Electrophoresis," *Analytical Biochemistry*, vol. 86, pp. 655–664, (1978). month unknown.

Andreas Chrambach, et al., "Selected buffer systems for moving boundary electrophoresis on gels at various pH values, presented in a simplified manner," *Electrophoresis*, vol. 4, pp. 190–204, (1983). month unknown.

Michael W. Hunkapiller, et al., "Isolation of Microgram Quantities of Proteins from Polyacrylamide Gels for Amino Acid Sequence Analysis," *Methods in Enzymology*, vol. 91, pp. 227–232, (1983). month unknown.

Jack Kyte, et al., "A Discontinuous Electrophoretic System for Separating Peptides on Polyacrylamide Gels," *Academic Press, Inc.*, pp. 515–522, (1983). month unknown.

Anthony T. Andrews, "Electrophoresis, Theory, Techniques, and Biochemical and Clinical Applications", *Oxford Science Publications*, Second Edition, pp. 79–92, (1986). month unknown.

A.T. Andrews, Electrophoresis, Oxford Univ. Press, pp. 20 & 126, (1986). month unknown.

Malcolm Moos, Jr., et al., "Reproducible High Yield Sequencing of Proteins Electrophoretically Separated and Transferred to an Inert Support," *The Journal of Biological Chemistry*, vol. 263, No. 13, pp. 6005–6008, (1988). month unknown.

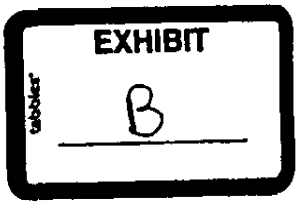
(List continued on next page.)

Primary Examiner—Jill Warden
Assistant Examiner—Alex Noguerola
Attorney, Agent, or Firm—Fish & Neave; Edward J. DeFranco; Adam P. Noah

[57] **ABSTRACT**

A gel and buffer system for gel electrophoresis wherein separation occurs at neutral pH.

22 Claims, No Drawings



OTHER PUBLICATIONS

Kenneth G. Christy, Jr., et al., "Modifications for SDS–Page of Proteins", *BioTechniques*, vol. 7, No. 7, pp. 692–693, (1989). month unknown.

Jeffery, D. Fritz, et al., "Factors Affecting Polyacrylamide Gel Electrophoresis and Electroblotting of High–Molecular–Weight Myofibrillar Proteins," *Analytical Biochemistry*, vol. 180, pp. 205–210, (1989). month unknown.

K. Nakamura et al., Electrophoresis, pp. 10, 29–33, (1989). month unknown.

B.D. Hames, et al., "Gel Electrophoresis of Proteins, A Practical Approach," *The IRL Press at Oxford University Press*, Second Edition, pp. 1–50, (1990). month unknown.

Jens Wiltfang, et al., "A new multiphasic buffer system for sodium dodecly sulfate–polyacrylamide gel electrophoresis of proteins and peptides with molecular masses 100 000–1000, and their detection with picomolar sensitivity," *Electrophoresis*, vol. 12, pp. 352–366, (1991). month unknown.

"Migration Tables" and "Buffer Selection Guide," NOVEX Brochure, (1991). month unknown.

Wayne F. Patton, et al., "Tris–Tricine and Tris–Borate Buffer Systems Provide Better Estimates of Human Mesothelial Cell Intermediate Filament Protein Molecular Weights than the Standard Tris–Glycine System," Analytical Biochemistry, vol. 197, pp. 25–33 (Aug. 15, 1991). month unknown.

"Electrophoresis, The NOVEX System: The Fast, Easy Way To Your Answer!," NOVEX Brochure (1992). month unknown.

Martin de Llano, et al., "Increased electrophoretic mobility of sodium sulfite–treated jack bean urease," *Electrophoresis*, vol. 13, pp. 300–304, (1992).

Harold Swerdlow, et al., "Stability of capillary gels for automated sequencing of DNA," *Electrophoresis*, vol. 13, pp. 475–483, (1992).

"Technically Speaking . . . , NOVEX Pre–mixed Buffers, Fast, Easy, Reproducible Electrophoresis Buffers," NOVEX Brochure (1993).

Suraj P. Bhat, "DNA Sequencing on Minigels: An Alternative Technique for routine Analysis," *Academic Press, Inc.*, pp. 560–562, (1993).

Harold Swerdlow, et al., "Reloading and Stability of Polyacrylamide Slab Gels for Automated DNA Sequencing," *BioTechniques*, vol. 16, No. 4, pp. 684–693, (1994).

Piero Carninci, et al., "A discontinuous buffer system increasing resolution and reproducibility in DNA sequencing on high voltage horizontal ultrathin–layer electrophoresis," *Electrophoresis*, vol. 16, pp. 1836–1845, (1995).

Robert C. Allen,et al., "Discontinuous electrophoresis revisited: A review of the process," *Applied and Theoretical Electrophoresis*, vol. 6, pp. 1–9, (1996).

"The Protein Society," Protein Science Program & Abstracts, vol. 5, Suppl. 1 (1996).

David Lide, editor, CRC Handbook of Chemistry & Physics, 77th edition, p. 7–12, (1996–97).

SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL

This application is a continuation of copending application Ser. No. 08/730,678, filed Oct. 11, 1996 now U.S. Pat. No. 5,922,185, which is a continuation-in-part of copending application Ser. No. 08/221,939, filed Mar. 31, 1994, now U.S. Pat. No. 5,578,180, the disclosure of which is incorporated by reference herein in its entirety.

This invention relates to techniques for gel electrophoresis. More particularly this invention relates to a novel system for gel electrophoresis at approximately neutral pH.

BACKGROUND OF THE INVENTION

Gel electrophoresis is a common procedure for the separation of biological molecules, such as deoxyribonucleic acid (DNA), ribonucleic acid (RNA), polypeptides and proteins. In gel electrophoresis, the molecules are separated into bands according to the rate at which an imposed electric field causes them to migrate through a filtering gel.

The basic apparatus used in this technique consists of a gel enclosed in a glass tube or sandwiched as a slab between glass or plastic plates. The gel has an open molecular network structure, defining pores which are saturated with an electrically conductive buffered solution of a salt. These pores through the gel are large enough to admit passage of the migrating macromolecules.

The gel is placed in a chamber in contact with buffer solutions which make electrical contact between the gel and the cathode or anode of an electrical power supply. A sample containing the macromolecules and a tracking dye is placed on top of the gel. An electric potential is applied to the gel causing the sample macromolecules and tracking dye to migrate toward the bottom of the gel. The electrophoresis is halted just before the tracking dye reaches the end of the gel. The locations of the bands of separated macromolecules are then determined. By comparing the distance moved by particular bands in comparison to the tracking dye and macromolecules of known mobility, the mobility of other macromolecules can be determined. The size of the macromolecule can then be calculated.

The rate of migration of macromolecules through the gel depends upon three principle factors: the porosity of the gel; the size and shape of the macromolecule; and the charge density of the macromolecule. It is critical to an effective electrophoresis system that these three factors be precisely controlled and reproducible from gel to gel and from sample to sample. However, maintaining uniformity between gels is difficult because each of these factors is sensitive to many variables in the chemistry of the gel system.

Polyacrylamide gels are commonly used for electrophoresis. Polyacrylamide gel electrophoresis or PAGE is popular because the gels are optically transparent, electrically neutral and can be made with a range of pore sizes. The porosity of a polyacrylamide gel is in part defined by the total percentage of acrylamide monomer plus crosslinker monomer ("%T") it contains. The greater the concentration, the less space there is between strands of the polyacrylamide matrix and hence the smaller the pores through the gel. An 8% polyacrylamide gel has larger pores than a 12% polyacrylamide gel. An 8% polyacrylamide gel consequently permits faster migration of macromolecules with a given shape, size and charge density. When smaller macromolecules are to be separated, it is generally preferable to use a gel with a smaller pore size such as a 20% gel. Conversely for separation of larger macromolecules, a gel with a larger pore size is often used, such as an 8% gel.

Pore size is also dependent upon the amount of crosslinker used to polymerize the gel. At any given total monomer concentration, the minimum pore size for a polyacrylamide gel is obtained when the ratio of total monomer to crosslinker is about 20:1, (the usual expression for this ratio would be "15%C").

Several factors may cause undesirable variation in the pore size of gels. Pore size can be increased by incomplete gel polymerization during manufacture. Hydrolysis of the polyacrylamide after polymerization can create fixed negative charges and break down the crosslinks in the gel, which will degrade the separation and increase the pore size. An ideal gel system should have a reproducible pore size and no fixed charge (or at least a constant amount) and should be resistant to change in chemical characteristics or the pore size due to hydrolysis.

The size of the macromolecule varies between different macromolecules; the smaller and more compact the macromolecule the easier it will be for the macromolecule to move through the pores of a given gel. Given a constant charge density, the rate of migration of a macromolecule is inversely proportional to the logarithm of its size.

For accurate and reproducible electrophoresis, a given type of macromolecule should preferably take on a single form in the gel. One difficulty with maintaining uniformity of the shape of proteins during gel electrophoresis is that disulfide bonds can be formed by oxidation of pairs of cysteine amino acids. Different oxidized forms of the protein then have different shapes and, therefore, migrate through the gel run with slightly different mobilities (usually faster than a completely reduced protein, since the maximum stokes radius and minimum mobility should occur with a completely unfolded form). A heterogeneous mixture of forms leads to apparent band broadening. In order to prevent the formation of disulfide bonds, a reducing agent such as dithiothreitol (DTT) is usually added to the samples to be run. The shape of DNA and RNA macromolecules is dependent on temperature. In order to permit electrophoresis on temperature-dependent DNA and RNA molecules in their desired form, separations are done at a controlled temperature.

The charge density of the migrating molecule is the third factor affecting its rate of migration through the gel—the higher the charge density, the more force will be imposed by the electric field upon the macromolecule and the faster the migration rate subject to the limits of size and shape. In SDS PAGE electrophoresis, the charge density of the macromolecules is controlled by adding sodium dodecyl sulfate (SDS) to the system. SDS molecules associate with the macromolecules and impart a uniform charge density to them, substantially negating the effects of any innate molecular charge. Unlike proteins, the native charge density of DNA and RNA is generally constant, due to the uniform occurrence of phosphate groups. Thus, charge density is not a significant problem in electrophoresis of DNA and RNA.

SDS PAGE gels are usually poured and run at basic pH. The most common PAGE buffer system employed for the separation of proteins is that developed by Ornstein (1) and modified for use with SDS by Laemmli (2). Laemmli, U. K. (1970) *Nature* 227, 680–686. The Laemmli buffer system consists of 0.375 M tris (hydroxy methyl) amino-methane (Tris), titrated to pH 8.8. with HCl, in the separating gel. The stacking gel consists of 0.125 M Tris, titrated to pH 6.8. The anode and cathode running buffers contain 0.024 M Tris, 0.192 M glycine, 0.1% SDS. An alternative buffer system is disclosed by Schaegger and von Jagow. Schaegger, H. and

von Jagow, G., *Anal. Biochem.* 1987, 166, 368–379. The stacking gel contains 0.75 M Tris, titrated to pH 8.45 with HCl. The separating gel contains 0.9 M Tris, titrated to pH 8.45 with HCl. The cathode buffer contains 0.1 M N-tris(hydroxymethyl)methylglycine (tricine), 0.1% SDS. The anode buffer contains 0.2 M Tris, titrated to pH 8.9 with HCl. For both of these systems Tris is the "common ion" which is present in the gel and in the anode and cathode buffers.

In the Laemmli system, the pH of the trailing phase in the stacking gel is about 8.9. In the separating gel, the trailing phase pH is about 9.7. At this pH, primary amino groups of proteins react readily with unpolymerized acrylamide, thiol groups are more subject to oxidation to disulfides, or reaction with unpolymerized polyacrylamide, than at neutral pH and acrylamide itself is subject to hydrolysis.

The shape of the DNA and RNA macromolecules is also dependent on a fourth important factor, temperature. The temperature-dependent shape of DNA and RNA is caused by the interaction of two macromolecules containing complementary sequences and the interaction of complementary sequences in a single macromolecule. Some techniques require that the DNA remain in its double-stranded form. Typically, such separations are done in Tris borate ethylene diamine tetra-acetic acid (TBE) buffer, consisting of 0.09 M Tris, 0.09 M boric acid, and 0.002 M ethylene diamine tetra-acetic acid (EDTA) on either polyacrylamide or agarose gels. In general, these separations are done at lower temperatures to maintain the double-stranded structure. In the absence of denaturants, DNA's and RNA's structure is fairly stable and not significantly affected by temperature.

In other techniques, dissociation of the two DNA strands (known as "melting") is utilized to effect the separation. Such methods require careful temperature control in order to produce a consistent separation. One method, non-isotopic single-strand conformational polymorphism ("Cold SSCP"), utilizes a dissociative sample buffer with heat to melt the strands, a TBE buffer, and a polyacrylamide gel. In Cold SSCP, temperatures of 4 to 35° C. are used to allow variable-conformation renaturation to occur between mutant strands, and temperature changes of only a few degrees can significantly alter the number of mutants seen. See Hongyo, et al., *Nucleic Acids Research*, 21, 3637 (1993). Another method, employed in DNA sequence analysis, typically utilizes TBE buffers containing 6 to 8 M urea and/or 2 to 12 M formamide, and elevated temperatures. It is important that the temperature remain high enough—typically 45 to 55° C.—to maintain fully melted DNA or RNA. Gels are usually polyacrylamide and sometimes substituted acrylamide polymers. For example, certain alkyl-substituted polyacrylamide gels are described in Shoor et al., U.S. Pat. No. 5,055,517.

These DNA and RNA separation methods are characterized by the use of continuous buffer systems, which use the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber, and the cathode chamber. These buffers usually are comprised of Tris and boric acid with EDTA added to inhibit hydrolytic enzyme activity. The TBE buffer system typically does not provide good stability when used in pre-cast gels, made and stored for periods of weeks at 4° C. The polymer tends to break down, generating a fixed charge which leads to distortion particularly at the cathode end of the gel where resolution is especially important. Urea also tends to break down under alkaline pH at 4° C. When large concentrations of urea are present, the ionic breakdown products can be present at a large enough concentration to disrupt the separation and cause loss of resolution.

Other buffer systems for DNA and RNA separations employ Tris/acetate, Tris/phosphate, and Tris/glycylglycine. While these buffer systems may be formulated near pH 7, the PK_a of Tris causes them to shift to an alkaline pH during electrophoresis especially near the cathode. The applicants have found that the polyacrylamide and urea tend to break down during electrophoresis for DNA sequencing due to the high temperatures (50° C.) employed for several hour runs when Tris is used as the buffering base. This breakdown leads to higher current and lower resolution than might be obtained with a neutral pH buffer system, so that the DNA sequence read length is reduced and read errors are increased.

The need for uniformity and predictability is magnified in precast electrophoresis gels which are manufactured by an outside vendor and then shipped to the laboratory where the electrophoresis will be performed. Precast gels must control the properties discussed above and they must be able to maintain this control throughout shipping and storage. The shelf life of many precast gels is limited by the potential for hydrolysis of acrylamide and/or buffer constitution during storage at the high pH of the gel buffer.

It is a disadvantage of a high pH gel that the polyacrylamide gel is subject to degradation by hydrolysis and has a limited shelf-life.

It is a further disadvantage of a high pH gel that proteins react readily with unpolymerized acrylamide which may interfere with subsequent analysis of the protein such as peptide sequencing.

It is a still further disadvantage of a high pH gel that thiol groups are subject to oxidation to disulfides causing a decreased resolution of separated macromolecules.

It is a further disadvantage of a high pH gel that buffer constituents such as urea break down readily.

SUMMARY OF THE INVENTION

It is an object of this invention to produce a neutral gel system that reduces protein reaction with unpolymerized acrylamide thereby enhancing yield and resolution.

It is a further object of this invention to produce a neutral gel system that prevents formation of disulfides from free thiol groups thereby enhancing yield and resolution.

It is also an object of this invention to produce a neutral gel system that reduces degradation of the polyacrylamide gel by hydrolysis thereby increasing the stability of a gel during electrophoresis and the useful shelf-life of a precast gel, and better resolution.

It is also an object of this invention to produce a neutral gel system that reduces breakdown of buffer constituents, such as urea.

In accordance with this invention, applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Applicants also describe a gel and buffer system wherein storage of the gel and subsequent electrophoresis of macromolecules (such as DNA, RNA, polypeptides and proteins) occurs at neutral pH. The above and other objects and advantages of the present invention will be apparent upon consideration of the following detailed description.

DETAILED DESCRIPTION OF THE INVENTION

Applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Advantageously, at this neutral pH, primary amino groups of proteins react less readily with unpolymer-

ized acrylamide because protonation of protein amino groups greatly reduces their reactivity to acrylamide or other related blocking agents. Furthermore, at this neutral pH, thiol groups are less subject to oxidation than at higher pH and polyacrylamide itself is less subject to hydrolysis.

The result is a gel system with improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers without reducing agents and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance. An additional benefit is that a single gel recipe, using the same buffer for the stacking and separating gels, can be used with two different running buffers to give two separation systems. Using this feature, an 8% gel, for example, can cover a protein separation range of 2 to 200 kDa.

In one embodiment of this invention a polyacrylamide gel of between about 3% and about 25% (%T) acrylamide is polymerized using from about 1% to about 6% crosslinker (%C) using a gel buffer comprising a primary organic amine or substituted amine with a PK_a near neutrality, titrated with approximately half as much HCl (on a molar basis), so that the pH of the buffer is approximately neutral. In a preferred embodiment the gel is polymerized using from about 2% to about 5% crosslinker (%C) using a gel buffer comprising bis-(2-hydroxyethyl) iminotris (hydroxymethyl) methane (Bis-Tris) titrated with HCl. Different separation characteristics can be obtained by running the gel with either a 3-(N-morpholino) propanesulfonic acid (MOPS) or 2-(N-morpholino) ethanesulfonic acid (MES), buffer. 2 mM to 10 mM thioglycolic acid (TGA) or 2 mM to 10 mM sodium bisulfite is added to the running buffer to maintain a reducing environment in the gel during electrophoresis.

Applicants also describe another gel and buffer system for separation of macromolecules (including DNA, RNA, polypeptides and proteins) wherein separation occurs at neutral pH. This gel and buffer system may be a discontinuous or continuous buffer system, but is particularly useful in a continuous system. A continuous buffer system is one using the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber and the cathode chamber. This gel and buffer system permits higher resolution during electrophoresis when alkaline-labile compounds such as polyacrylamide and urea are present. This gel and buffer system also permits higher resolution when elevated temperatures are used. Advantageously, at this neutral pH, urea is less subject to hydrolysis. Furthermore, polyacrylamide itself is less subject to hydrolysis.

This gel and buffer system also possesses improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance.

In an embodiment of this gel and buffer system an electrophoresis gel is uniformly saturated with a gel buffer solution comprising a primary organic amine or substituted amine with a pK_a near neutrality, titrated with approximately an equimolar amount of acid or zwitterionic compound, so that the pH of the buffer is between about pH 6 and pH 8, preferably between PH 5.5 to pH 7.5, and most preferably 6.5 to 7.0. The electrophoresis gel may be any agarose or polyacrylamide gel. Preferably, the electrophoresis gel comprises between 3% and 25% (%T) acrylamide polymerized using from about 1% to about 6% cross linker (%C). More preferably, this polyacrylamide gel is polymerized using from about 2% to about 5% crosslinker (%C). Preferably, the amine comprises Bis-Tris or N-(2-hydroxyethyl) morpholine, and most preferably, Bis-Tris. Suitable acids and zwitterionic compounds are hydrochloric acid, tricine, acetic acid, piperazine-N,N'-2-ethanesulfonic acid, 3-(N-morpholino)-propanesulfonic acid, 2-(N-morpholino) ethanesulfonic acid, N-(2-acetamido)-2-aminoethanesulfonic acid, 2-(N-morpholino)-2-hydroxypropanesulfonic acid, N-tris-(hydroxymethyl)-2-ethanesulfonic acid, N-2-hydroxyethyl-piperazine-N-2-ethanesulfonic acid, N,N-bis-(hydroxyethyl)-2-aminoethanesulfonic acid, and 3-(N-tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid. Tricine, 2-(N-morpholino)-ethanesulfonic acid, and piperazine-N, N'-2-ethanesulfonic acid are preferred for use in the buffer for a continuous gel and buffer system for separation of DNA and RNA because the resulting system has separation characteristics similar to the commonly used TBE gel systems. Tricine is most preferred for that use. Preferably, the gel buffer comprises Bis-Tris titrated with tricine.

In a gel and buffer system, current increases and migration rates decline as the performance of the gels decline. The increase in current has been attributed to alkaline-catalyzed hydrolysis of urea present at 36% to 42% concentration. Any breakdown in a neutral substance present at a large concentration, which produces a charged species will tend to disrupt the electrophoresis. This disruption arises from the extra current produced, which in turn increases joule heating without aiding the separation. In addition, a discontinuity arises from the anionic and cationic hydrolysis-products forming in the gel that are not present in the cathode and anode buffers. Hydrolysis of gel buffer species or additives takes place independently from the gel matrix composition. The decrease in migration rate may be attributed to higher fixed charge in the gel caused by alkaline-catalyzed hydrolysis of the gel's polyacrylamide. The fixed charge leads to significant counter-flow of water, which can retard a macromolecule's migration rate. It has been found that problems of gel instability producing lower resolution, increased current, decreased migration rates can be solved with gels buffered near neutrality and with buffer substances having a pK_a near neutrality. Such buffering systems improve the performance of fresh or pre-cast polyacrylamide gels, and fresh or pre-cast gels containing alkaline-labile materials, such as urea or formamide, even when the gels are made with base-stable polymers.

The inventors also have discovered the value of using different buffer substances in the cathode, gel, and anode buffers. A group of substitutions relating to cost and throughput have been discovered. The anionic substance used in the gel or the cathode buffer need not be present in the anode buffer since the anions do not migrate out of the anode buffer. In fact, the use of chloride or other strong acids in the anode buffer serves to increase the conductance of the buffer, thereby increasing the net voltage drop across the gel and decreasing run times. Such acids are also typically much less expensive as compared to those employed in the cathode buffer. Similarly, the base used to adjust the pH of the cathode buffer need not be the same as that used in the gel. At a neutral pH, sodium hydroxide, Tris, and other organic bases with a basic pK_a have a higher conductance and often lower cost than Bis-Tris or other bases with a pK_a near neutrality. Using sodium or Tris salts in the cathode buffer

will also decrease the gel run times. Often, the anode and cathode buffers are used at a higher concentration than in the gel, further increasing their conductance and decreasing gel run times. Thus, using different, more conductive anode and cathode buffer species than in the gel buffer increases throughput and decreases costs.

It was also found that Tris or Bis-Tris may be used in the anode buffer with no visible effect on the separation quality. Because of its higher pK_a, Tris gradually infiltrates the anode end of the gel increasing that region's conductance, causing the voltage drop to fall locally. Thus, the macromolecules near the anode slow down and the separation compresses, while the macromolecules near the cathode experience a higher voltage drop increasing their migration and relative separation. This effect of Tris actually improves the resolution of macromolecules at the cathode end of the gel where it is most needed. Tris is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris and can improve read lengths.

The preferred embodiment of this invention uses Tris chloride in the anode buffer, the sodium or Tris salt of the acid or zwitterionic compound in the cathode buffer, and Bis-Tris as the gel buffer amine. For protein and polypeptide separations, the most preferred cathode buffers are sodium or Tris salts of MOPS and MES, combined with a Bis-Tris chloride gel buffer. For DNA and RNA separations, the most preferred cathode buffers are sodium or Tris salts of tricine, combined with a Bis-Tris tricine EDTA running buffer. When the buffer chambers are small, the most preferred molar concentrations of the cathode and anode buffers are five times that present in the gel buffer. These buffer systems provide the benefits of a neutral pH gel during both storage and running, the least cost, and the fastest run times.

These and other embodiments can be understood by reference to the following illustrative and comparative examples.

EXAMPLES

Tris, Bis-Tris, MES, tricine, MOPS and Piperazine-N,N'-2-ethanesulfonic acid (PIPES) were purchased from Sigma (St. Louis, Mo.) or Research Organics (Cleveland, Ohio). Thioglycolic acid (TGA), dithiothreitol (DTT) and beta-mercaptoethanol (BME) were from Sigma. All other chemicals were reagent, "ultra pure" or "electrophoresis grade" from standard sources.

In Example 1 through 6, gels were cast in 1 mm thickness mini-gel cassettes from NOVEX (San Diego Calif.) and run in an X-Cell minicell. The Bis-Tris separating gel and stacking gels were prepared from a 30%T/2.5%C acrylamide/BIS stock solution and a 7X Bis-Tris stock solution (2.5 M Bis-Tris, 1.5 M HCl, pH 6.5). To prepare the separating gel, the stock solutions were blended with ultra pure water to a final concentration 8%T, 0.357 M Bis-Tris, to which was added 0.2 ul/ml N,N,N',N'-tetra-methyl-ethylene-diamine (TEMED). After degassing, 2.0 ul/ml of a 10% solution of ammonium persulfate (APS) was added, the gel was immediately poured into the cassette then overlaid with water. Polymerization was allowed to proceed for at least 30 minutes at room temperature (RT), the water was removed and a 4% stacking gel applied. The stacking gel was prepared in the same fashion as the separating gel, except that the final concentration obtained was 4%T, the TEMED concentration was increased to 0.4 ul/ml and the APS solution increased to 5.0 ul/ml. MOPS running buffer consisted of 50 mM MOPS, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. MES running buffer consisted of 50 mM MES, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. Sample buffer (2X) consisted of 0.25 M Bis-Tris, 0.15 M HCl, 10% (w/v) Glycerol, 2% SDS, 1 mM EDTA, 0.03% Serva Blue G, and 200 mM DTT. Samples containing a set of protein standards were heated for 15 min at 70 degrees before application. Bovine serum albumin (BSA), chicken egg ovalbumin, alkylated insulin A and B chain, soybean trypsin inhibitor, and bovine erythrocyte carbonic anhydrase were included in the standard. Sample volume was 5 ul in all cases.

Example 1

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the absence of a reducing agent. The resulting separation pattern was very similar to that obtained on an 8% Tris/glycine gel (Laemmli), with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The BSA band was somewhat diffuse and shifted toward the anode. The Ovalbumin band was also somewhat diffuse.

Example 2

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of TGA in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without TGA.

Example 3

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of sodium bisulfite in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without sodium bisulfite.

Example 4

The protein standards were separated on an 8% Bis-Tris/Cl gel with MES running buffer in the absence of a reducing agent. The protein separation was very similar to that obtained from an 12% Tris/tricine (Schaegger) gel. All proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). When the gel is run without TGA, soybean trypsin inhibitor had a more prominent doublet.

Example 5

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of TGA in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Example 6

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of

sodium bisulfite in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Although MES and MOPS were selected as desirable running buffers for protein separation because the resulting system has separation characteristics similar to the commonly used Laemmli and Schaegger gel systems, it was found that a range of buffers are suitable for use in this system. Among the additional buffers giving good results were [N-(2-acetamido)]-2-aminoethanesulfonic acid (ACES), 2-[Nmorpholino]-2-hydroxypropanesulfonic acid (MOPSO), N-Tris-(hydroxymethyl)-2-ethanesulfonic acid (TES), N,N-bis-(hydroxyethyl)-2-aminoethanesulfonic acid (BES), N-2-hydroxyethyl-piperazine-N-2-ethanesulfonic acid (HEPES), and 3-(N-Tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid (TAPSO).

All the proteins that exhibit some band broadening and/or mobility shifts when run in the absence of TGA or sodium bisulfite, have in common a composition that includes multiple cysteines (BSA, for instance, has 35 cysteines). On the other hand carbonic anhydrase, which always runs cleanly, has no cysteines. Moreover, if the reduced proteins are alkylated before running, they run as sharp homogeneous bands even in the absence of a reducing agent.

Cysteine-containing proteins appear to give generally sharper bands in the Laemmli system than the neutral system, when both are run with 100 mM mercaptoethanol or DTT in the sample buffer but without TGA in the running buffer. Since thiol oxidation is more favored as the pH increases, it would be expected that the higher pH of the Laemmli system would cause oxidation of disulfide to be at least as pronounced as it is in the neutral pH system. However, DTT and similar "neutral" thiol reducing agents are weak acids (with pK_a's around pH 8–9). Thus, at basic pH, these reducing agents migrate into the gel and, if present at sufficient concentration, provide some protection against oxidation of sulfhydryls. At a neutral separating pH, DTT from the sample buffer is in an uncharged form and will remain behind in the sample well. Thus, no reducing agent migrates into the gel.

To maintain proteins in a reduced form during electrophoresis at neutral pH, it was found advantageous to use a reducing agent that would migrate into the gel at neutral pH. Sodium bisulfite (2–10 mM) was found to maintain a reducing environment in the gel during electrophoresis. Fully reduced TGA (or similar negatively charged thiols) give similar results at comparable concentrations. However, partially oxidized TGA will promote partial oxidation of protein thiols. Because reduction (oxidation) of protein thiols will take place via disulfide interchange, the ratio of reduced to oxidized thiols in the protein will substantially reflect the ratio of reduced to oxidized thiols in the TGA. Conversely, sulfite oxidizes to sulfate, which does not participate in redox reactions under conditions found in the gel. Therefore, regardless of the sulfite/sulfate ratio in a partially oxidized preparation of sulfite, as long as sufficient sulfite remains, proteins will be protected against thiol oxidation.

It was also found that Tris could be substituted for Bis-Tris in the running buffer with no visible effect on the separation quality. Bis-Tris may be preferred where the protein will be intentionally modified post-separation. Bis-Tris is a tertiary amine and will not interfere with the protein modifying agents which react through primary amines. Tris, however, is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris.

Example 7

A 14.7%T/5%C TBE urea gel was made in the following manner. To prepare the separating gel solution, a 30% acrylamide/ 1.6% bis-acrylamide stock solution (47.5 ml), and a 5X gel buffer stock solution containing 0.45 M Tris, 0.45 M boric acid, and 0.01 M EDTA, pH 8.18 (20 ml) were mixed with urea (36 g), TEMED (20 ul), and enough water was added to make 100 ml. The final solution pH was 8.87. It was degassed, a 10% ammonium persulfate solution ("10% APS") (12.8 ul) was added to 6.4 ml, and poured into a 1 mm thick mini-gel cassette from NOVEX (San Diego, Calif.). A comb-forming gel solution was made similarly, with the following differences: acrylamide/bis solution (12.7 ml), TEMED (50 ul), and no urea; to 1.0 ml of this solution was added 10% APS (0.1 Ml) and it was immediately poured on top of the separating gel solution. A 1 mm 10-well comb (NOVEX) was added, and the gels were allowed to polymerize for at least 30 minutes at room temperature. They were then run after storage in sealed pouches with 1 X gel buffer containing 7 M at different temperatures.

The gels were run fresh or after storage at either 4° C. or 35° C. Samples employed were a 10b Oligo DNA standard (BRL, Bethesda, Md.) or an 18-mer customsynthesized DNA fragment (Synthetic Genetics, San Diego, Calif.). Gels were run in an X-Cell mini-cell (NOVEX) at 180 volts for 80 minutes, using 1X gel buffer in both the anode and cathode chambers. Finally, the bands were visualized by treating with Stains-All solution (Sigma) for 15 minutes then destaining in 20% methanol for 10 minutes.

Compared to fresh gels, the gels stored at 4° C. showed a gradual loss of band sharpness and an increase in current during the electrophoresis. The loss of sharpness leads to less resolution between bands. After 2 weeks at 4° C., the band width had doubled as compared to fresh gel bands. When stored at 35° C. for 1 week, the gels ran with higher current but the dye front only migrated 80% as far in 80 minutes. The gel itself retained the stain, and the bands were fuzzy and indistinct. After three weeks, no bands could be seen and the gels were very fragile.

Example 8

Gels were prepared, stored, and run as described in Example 7, except that the 5X gel buffer was composed of 0.45 M Bis-Tris, 0.45 M tricine, and 0.01 M EDTA pH 7.27, the final gel solution pH was 7.70, and the running buffer was 0.05 M Tris, 0.05 M tricine, 0.001 M EDTA. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to 3 weeks at 35° C. or for several months at 4° C.

Example 9

Gels were prepared, stored, and run as described in Example 7, except that the 5X gel buffer was composed of 0.125 M N-(2-hydroxyethyl) morpholine (HEM), 0.083 M acetic acid, and 0.002 M EDTA pH 7.0, and the final gel solution pH was 7.21. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to three weeks at 35° C. or for several months at 4° C. However, the gels turned yellow on storage at 35° C.

Example 10

Mini-DNA sequencing gels were prepared from the same separating gel solution as described in Example 7, except

that only 23.3 ml of acrylamide/bis solution was employed, the urea was increased to 42 g, and the TEMED was increased to 50 ul. It was used without degassing by adding 10% APS (50 ul) to 10 ml of the solution, and pouring between 11 cm wide by 22 cm long thick glass plates with 0.25 mm spacers. The gels were allowed to polymerize for 60 minutes at room temperature, then run the same day.

Samples employed were an M-13 DNA sequencing reaction prepared with S^{35}-label using a USB Sequenase kit, version 2 (United States Biochemicals, Cleveland, Ohio). They were run in a custom-made DNA sequencing chamber at 15 watts (about 50° C.). Finally, the bands were visualized by autoradiography. The gels had a read length of 120 bases with a 5% error rate (95% accuracy).

Example 11

Gels were prepared and run as in Example 10, except that the 5x gel buffer was composed of 0.5 M Bis-Tris, 0.84 M tricine, and 0.01 M EDTA pH 7.2 and the final gel solution pH was 7.50. The gels had a read length of 137 bases with a 1.5% error rate (98.5% accuracy).

Example 12

The separating gel solution was prepared as in Example 7, except that a SoaneGel SQ solution (a solution of substituted acrylamide and substituted bis-acrylamide cross-linkers, available from Soane Biosciences Inc., Hayward, Calif.) was used for the polymer at 6%T, and the TEMED was increased to 88 ul. After initiation of the gel solution (40 ml) with 10% APS (200 ul), the gels were poured in plates with 0.35 mm spacers for an ABI Model 377 DNA Sequencer (Applied Biosystems Division of Perkin Elmer Corp., Foster City, Calif.), and allowed to polymerize at room temperature for 2 hours. The gels were loaded with a pGEM sequencing reaction and run with 1X TBE buffer at 30 V/cm, generating 55° C. They had a read length of 815 bases; at 550 bases the error rate was 1.5% (98.5% accuracy).

Example 13

Gels were prepared and run as in Example 12, except that the 5X gel buffer was composed of 0.5 M Bis-Tris, 0.84 M tricine, and 0.01 M EDTA pH 7.2, and the final gel solution pH was 7.5. The gels were run with 1X gel buffer at 30 V/cm, generating 55° C., and had a read length of 866 bases; at 550 bases the error rate was 1.1% (98.9% accuracy).

Although the invention has been explained in relation to its preferred embodiments, it is to be understood that various modifications thereof will become apparent to those skilled in the art. The foregoing disclosure is not intended or to be construed to limit the present invention, or to otherwise exclude any such other embodiments, adaptions, variations and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

We claim:

1. A discontinuous buffer gel electrophoresis system comprising:

an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel saturated with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

a cathode buffer comprising an antioxidant that is anionic at neutral pH in a concentration sufficient to maintain proteins in a reduced state.

2. The system of claim 1, wherein the organic amine is Bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane.

3. The system of claim 1, wherein the electrophoresis gel is a polyacrylamide gel.

4. The system of claim 1, wherein the acid is selected from the group consisting of hydrochloric acid and acetic acid.

5. The system of claim 1, wherein the antioxidant comprises sulfite.

6. The system of claim 1, wherein the antioxidant comprises bisulfite.

7. The system of claim 1, wherein the antioxidant comprises a thiol.

8. The system of claim 1, wherein the antioxidant comprises thioglycolic acid.

9. The system of claim 1, wherein the gel buffer further comprises a dodecyl-sulfate salt.

10. The system of claim 9, wherein the dodecyl-sulfate salt is sodium dodecyl sulfate.

11. The system of claim 1, wherein the cathode buffer further comprises 3-(N-morpholino) propanesulfonic acid.

12. The system of claim 1, wherein the cathode buffer further comprises 2-(N-morpholino) ethanesulfonic acid.

13. A discontinuous buffer gel electrophoresis system comprising:

an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel saturated with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

a cathode buffer comprising an antioxidant that migrates into the electrophoresis gel by electrophoresis and that has a concentration sufficient to maintain proteins in a reduced state.

14. A discontinuous buffer gel electrophoresis system comprising:

an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel saturated with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

a cathode buffer comprising 3-(N-morpholino) propanesulfonic acid.

15. A discontinuous buffer gel electrophoresis system comprising:

an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel saturated with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

a cathode buffer comprising 2-(N-morpholino) ethanesulfonic acid.

16. A method for performing electrophoresis using a discontinuous buffer gel, the method comprising:

providing an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel;

saturating the separating gel with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

providing a cathode buffer comprising an antioxidant that is anionic at neutral pH in a concentration sufficient to maintain proteins in a reduced state.

17. The method of claim 16, wherein the organic amine is Bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane.

18. The method of claim 16, wherein the electrophoresis gel is a polyacrylamide gel.

19. The method of claim 16, wherein the acid is selected from the group consisting of hydrochloric acid and acetic acid.

20. The method of claim 16, wherein the gel buffer further comprises a dodecyl-sulfate salt.

21. The method of claim 20, wherein the dodecyl-sulfate salt is sodium dodecyl sulfate.

22. A method for performing electrophoresis using a discontinuous buffer gel, the method comprising:

providing an electrophoresis gel suitable for casting, the electrophoresis gel comprising a separating gel;

saturating the separating gel with a gel buffer comprising an organic amine with a pK_a near neutrality and an acid, the gel buffer having a pH between 5.5 and 7.5; and

providing a cathode buffer comprising an antioxidant that migrates into the gel by electrophoresis and that has a concentration sufficient to maintain proteins in a reduced state.

* * * * *

US006783651B1

(12) **United States Patent**
Updyke et al.

(10) **Patent No.: US 6,783,651 B1**
(45) **Date of Patent: *Aug. 31, 2004**

(54) **SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL**

(75) Inventors: **Timothy V. Updyke**, Temecula, CA (US); **Sheldon C. Engelhorn**, Cardiff-by-the-Sea, CA (US)

(73) Assignee: **Invitrogen Corporation**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 105 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/728,378**

(22) Filed: **Nov. 28, 2000**

Related U.S. Application Data

(63) Continuation of application No. 09/228,875, filed on Jan. 11, 1999, now Pat. No. 6,162,338, which is a continuation of application No. 08/730,678, filed on Oct. 11, 1996, now Pat. No. 5,922,185, which is a continuation-in-part of application No. 08/221,939, filed on Mar. 31, 1994, now Pat. No. 5,578,180.

(51) **Int. Cl.**[7] **G01N 27/453**
(52) **U.S. Cl.** **204/606**; 204/616; 204/469
(58) **Field of Search** 204/456, 468, 204/606, 616, 466

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,870,812	A	3/1975	Hayes, Jr. et al.	426/573
3,948,743	A	4/1976	Monthony et al.	204/461
4,139,440	A	2/1979	Chrambach et al.	204/454
4,209,373	A	6/1980	Bluestein et al.	204/168
4,481,094	A	11/1984	de Castro et al.	204/460
4,504,641	A	3/1985	Nochumson	526/238.2
4,542,200	A	9/1985	Nochumson	526/238.2
4,699,705	A	10/1987	Ogawa et al.	204/469
4,950,708	A	8/1990	Hochstrasser	524/728
5,110,434	A	5/1992	Zhu et al.	
5,120,413	A	6/1992	Chen et al.	
5,246,558	A *	9/1993	Chevigne et al.	204/468
5,275,708	A	1/1994	Akins et al.	204/468
5,334,708	A	8/1994	Chang et al.	530/391.5
5,370,777	A	12/1994	Guttman et al.	204/452
5,464,516	A	11/1995	Takeda et al.	204/468
5,578,180	A *	11/1996	Engelhorn et al.	204/468
5,922,185	A *	7/1999	Updyke et al.	204/466
6,059,948	A	5/2000	Updyke et al.	204/468
6,096,182	A	8/2000	Updyke et al.	204/468
6,143,154	A	11/2000	Updyke et al.	204/468
6,162,338	A *	12/2000	Updyke et al.	204/468

FOREIGN PATENT DOCUMENTS

AU	B-21926/95	10/1998	
EP	0 087 995 A1	2/1983	
EP	0 087 995 B1	2/1983	
EP	0 518 475 A1	12/1992	
EP	0 566 784 A1	10/1993	
EP	0 518 475 B1	4/1997	
EP	0753142 B1	8/1999	
EP	0 753 142 B1	8/1999	
JP	4-184163	7/1992	G01N/27/26
JP	5-203621	8/1993	G01N/27/447
JP	5-505877	8/1993	G01N/27/447
JP	5-322846	12/1993	G01N/27/447
KR	0368 955	1/2003	
WO	WO92/04625	3/1992	G01N/27/26
WO	94/23092	10/1994	
WO	WO 95/27197	10/1995	

OTHER PUBLICATIONS

P. 1111 of the 1992 May 1993 ICN catalog.*

Schajpal et al. ("Detection of GLO-I Isozymes in Human Blood by a Rapid Method," Annals of Biology, vol. 2, No. 1, pp. 90–92, 1986).*

Salvatore et al., ("Agarose Gel Electrophoresis System for the Separation of Antibiotics used in Animal Agriculture," Analyst, Mar. 1993, vol. 118).*

Stanescu et al. ("Proteoglycan Electrophoresis on Horizontal Submerged Polyacrylamide Agarose Gels," Connective Tissue Research, 1987, vol.16, pp. 71–77).*

Page 5 of Andrews, Elctrophoresis: Theory, Techniques, and Biochemical and Clinical applications, 2nd ed., Clarendon Press-Oxford 1986.*

Abou-Zeid et al., Characterization of fibronectin-binding antigens released by *Mycobacterium tuberculosis* and *Mycobacterium bovis* BCG. Infect. Immun. 56:3046–3051. Dec.*

Laemmli, Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature (London) 227:680–685, Aug.*

Sigma-Aldrich on-line catalog entry for Ultrogel AcA 54.*

Clayton et al. ("Amine-Citrate Buffers for pH Control in Starch Gel Electrophoresis," Journal of the Fisheries Research Board o Canada (1972), 29(8), 1169–72).*

Ratliff et al. ("Purification of a mycobacterial adhesion for fibronectin," Infection and Immunity (1993), 61(5), 1889–94).*

U.K. Laemmli, "Cleavage of Structural Proteins during the Assembly of the Head of Bacteriophage T4," *Nature*, 227, pp.680–685 (1970).

R. Ruechel, et al., *Hoppe-Seyler's Z. Physiol. Chem.*, 356(8), pp. 1283–1288, (1975). (translated abstract submitted previously).

H. Schagger, et al., "Tricine-Sodium Dodecyl Sulfate-Polyacrylamide Gel Electrophoesis for the Separation of Proteins in the Range from 1 to 100 kDa," *Anal. Biochem*, 166, pp. 368–379 (1987).

J. Sambrook, et al., *Molecular Cloninig: A Laboratory Manual*, second edition, vol. 1, pp. 6.6–6.13 (1989).

(List continued on next page.)

Primary Examiner—Alex Noguerola
(74) *Attorney, Agent, or Firm*—Sterne, Kessler, Goldstein & Fox P.L.L.C.

(57) **ABSTRACT**

A gel and buffer system for gel electrophoresis wherein separation occurs at neutral pH.

18 Claims, No Drawings

OTHER PUBLICATIONS

T. Hongyo, et al., "Cold SCCP: a simple, rapid and non-radioactive method for optimized single-strand conformation polymorphism analyses," *Nucleic Acids Research*, 21 (16), p. 3637–3642 (1993).

Samuel Raymond, et al., "Acrylamide Gel as a Supporting Medium for Zone Electrophoresis," *Science*, vol. 130, pp. 711–712, (1959).

Andrew C. Peacock, et al., "Molecular Weight Estimation and Separation of Ribonucleic Acid by Electrophoresis in Agarose–Acrylamide Composite Gels," *Biochemistry*, vol. 7, No. 2, pp. 668–674, (1968).

A. Chrambach, et al., "Experimental Validation of the Predicted Properties of a Multiphasic Buffer System Applied to Polyacrylamide Gel Electrophoresis", *Separ. Sci.*, 7 (6), 725–745, (1972).

Thomas M. Jovin, "Multiphasic Zone Electrophoresis. I, II & III Steady-State Moving-Boundary Systems Formed by Different Electrolyte Combinations," *Biochemistry*, vol. 12, No. 5, pp. 871–898, (1973).

Thomas M. Jovin, "Multiphasic Zone Electrophoresis. IV. Design and Analysis of Discontinuous Buffer Systems with a Digital Computer," *Annals New York Academy of Science, Jovin: Computer Design of Buffer Systems*, pp. 477–496, (1973).

CAPLUS abstract of Hoermann et al. ("Dissociation of fibrinogen and fibrin peptide chains by parital cleavages of disulfide bonds", *Hoppe-Seyler's Z. Physiol. Chem.* 1973, 354 (90), 1103–1111), Month Unknown.

R. Ruechel, et al., *Hoppe-Seyler's Z. Physiol. Chem.*, 356(8), pp. 1283–1288 (abstract), (1975).

Leslie C. Lane, "A Simple Method for Stabilizing Protein-Sulfhydryl Groups during SDS-Gel Electrophoresis," *Analytical Biochemistry*, vol. 86, pp. 655–664, (1978).

Andreas Chrambach, et al., "Selected buffer systems for moving boundary electrophoresis on gels at various pH values, presented in a simplified manner," *Electrophoresis*, vol. 4, pp. 190–204, (1983).

Michael W. Hunkapiller, et al., "Isolation of Microgram Quantities of Proteins from Polyacrylamide Gels for Amino Acid Sequence Analysis," *Methods in Enzymology*, vol. 91, pp. 227–232, (1983).

Jack Kyte, et al., "A Discontinuous Electrophoretic System for Separating Peptides on Polyacrylamide Gels," *Academic Press, Inc.*, pp. 515–522, (1983).

Anthony T. Andrews, "Electrophoresis, Theory, Techniques, and Biochemical and Clinical Applications", *Oxford Science Publications*, Second Edition, pp. 79–92, (1986).

A.T. Andrews, *Electrophoresis*, Oxford Univ. Press, pp. 20 & 126, (1986).

Malcolm Moos, Jr., et al., "Reproducible High Yield Sequencing of Proteins Electrophoretically Separated and Transferred to an Inert Support," *The Journal of Biological Chemistry*, vol. 263, No. 13, pp. 6005–6008, (1988).

Kenneth G. Christy, Jr., et al., "Modifications for SDS-PAGE of Proteins", *BioTechniques*, vol. 7, No. 7, pp. 692–693, (1989).

Jeffery, D. Fritz, et al., "Factors Affecting Polyacrylamide Gel Electrophoresis and Electroblotting of High-Molecular-Weight Myofibrillar Proteins," *Analytical Biochemistry*, vol. 180, pp. 205–210, (1989).

K. Nakamura et al., *Electrophoresis*, pp. 10, 29–33, (1989).

B. D. Hames, et al., "Gel Electrophoresis of Proteins, A Practical Approach," *The IRL Press at Oxford University Press*, Second Edition, pp. 1–50, (1990).

Jens Wiltfang, et al., "A new multiphasic buffer system for sodium dodecyl sulfate-polyacrylamide gel electrophoresis of proteins and peptides with molecular masses 100 000–1000, and their detection with picomolar sensitivity," *Electrophoresis*, vol. 12, pp. 352–366, (1991).

"Migration Tables" and "Buffer Selection Guide," NOVEX Brochure, (1991).

Wayne F. Patton, et al., "Tris-Tricine and Tris-Borate Buffer Systems Provide Better Estimates of Human Mesothelial Cell Intermediate Filament Protein Molecular Weights than the Standard Tris-Glycine System," *Analytical Biochemistry*, vol. 197, pp. 25–33 (Aug. 15, 1991).

"Electrophoresis, The NOVEX System: The Fast, Easy Way To Your Answer!," NOVEX Brochure (1992).

Martin de Llano, et al., "Increased electrophoretic mobility of sodium sulfite-treated jack bean urease," *Electrophoresis*, vol. 13, pp. 300–304, (1992).

Harold Swerdlow, et al., "Stability of capillary gels for automated sequencing of DNA," *Electrophoresis*, vol. 13, pp. 475–483, (1992).

"Technically Speaking . . . , NOVEX Pre-mixed Buffers, Fast, Easy, Reproducible Electrophoresis Buffers," NOVEX Brochure (1993).

Suraj P. Bhat, "DNA Sequencing on Minigels: An Alternative Technique for routine Analysis," *Academic Press, Inc.*, pp. 560–562, (1993).

Harold Swerdlow, et al., "Reloading and Stability of Polyacrylamide Slab Gels for Automated DNA Sequencing," *Biotechniques*, vol. 16, No. 4, pp. 684–693, (1994).

Piero Carninci, et al., "A discontinuous buffer system increasing resolution and reproducibility in DNA sequencing on high voltage horizontal ultrathin-layer electrophoresis," *Electrophoresis*, vol. 16, pp. 1836–1845, (1995).

Robert C. Allen, et al., "Discontinuous electrophoresis revisited: A review of the process", *Applied and Theoretical Electrophoresis*, vol. 6, pp. 1–9, (1996).

"The Protein Society", Protein Science Program & Abstracts, vol. 5, Suppl. 1 (1996).

David Lide, Editor, *CRC Handbook of Chemistry & Physics*, 77th edition, pp. p7–12, (1996–97).

Office Action from Japanese Patent Office Dated Dec. 9, 2003 for Japanese Patent Application No. 07–525759 (with Translation).

* cited by examiner

SYSTEM FOR PH-NEUTRAL STABLE ELECTROPHORESIS GEL

This application is a continuation of application Ser. No. 09/228,875, filed Jan. 11, 1999, now U.S. Pat. No. 6,162,338, which is a continuation of application Ser. No. 08/730,678, filed Oct. 11, 1996, now U.S. Pat. No. 5,922,185, which is a continuation-in-part of application Ser. No. 08/221,939, filed Mar. 31, 1994, now U.S. Pat. No. 5,578,180.

BACKGROUND OF THE INVENTION

Gel electrophoresis is a common procedure for the separation of biological molecules, such as deoxyribonucleic acid (DNA), ribonucleic acid (RNA), polypeptides and proteins. In gel electrophoresis, the molecules are separated into bands according to the rate at which an imposed electric field causes them to migrate through a filtering gel.

The basic apparatus used in this technique consists of a gel enclosed in a glass tube or sandwiched as a slab between glass or plastic plates. The gel has an open molecular network structure, defining pores which are saturated with an electrically conductive buffered solution of a salt. These pores through the gel are large enough to admit passage of the migrating macromolecules.

The gel is placed in a chamber in contact with buffer solutions which make electrical contact between the gel and the cathode or anode of an electrical power supply. A sample containing the macromolecules and a tracking dye is placed on top of the gel. An electric potential is applied to the gel causing the sample macromolecules and tracking dye to migrate toward the bottom of the gel. The electrophoresis is halted just before the tracking dye reaches the end of the gel. The locations of the bands of separated macromolecules are then determined. By comparing the distance moved by particular bands in comparison to the tracking dye and macromolecules of known mobility, the mobility of other macromolecules can be determined. The size of the macromolecule can then be calculated.

The rate of migration of macromolecules through the gel depends upon three principle factors: the porosity of the gel; the size and shape of the macromolecule; and the charge density of the macromolecule. It is critical to an effective electrophoresis system that these three factors be precisely controlled and reproducible from gel to gel and from sample to sample. However, maintaining uniformity between gels is difficult because each of these factors is sensitive to many variables in the chemistry of the gel system.

Polyacrylamide gels are commonly used for electrophoresis. Polyacrylamide gel electrophoresis or PAGE is popular because the gels are optically transparent, electrically neutral and can be made with a range of pore sizes. The porosity of a polyacrylamide gel is in part defined by the total percentage of acrylamide monomer plus crosslinker monomer ("% T") it contains. The greater the concentration, the less space there is between strands of the polyacrylamide matrix and hence the smaller the pores through the gel. An 8% polyacrylamide gel has larger pores than a 12% polyacrylamide gel. An 8% polyacrylamide gel consequently permits faster migration of macromolecules with a given shape, size and charge density. When smaller macromolecules are to be separated, it is generally preferable to use a gel with a smaller pore size such as a 20% gel. Conversely for separation of larger macromolecules, a gel with a larger pore size is often used, such as an 8% gel.

Pore size is also dependent upon the amount of crosslinker used to polymerize the gel. At any given total monomer concentration, the minimum pore size for a polyacrylamide gel is obtained when the ratio of total monomer to crosslinker is about 20:1, (the usual expression for this ratio would be "5% C").

Several factors may cause undesirable variation in the pore size of gels. Pore size can be increased by incomplete gel polymerization during manufacture. Hydrolysis of the polyacrylamide after polymerization can create fixed negative charges and break down the crosslinks in the gel, which will degrade the separation and increase the pore size. An ideal gel system should have a reproducible pore size and no fixed charge (or at least a constant amount) and should be resistant to change in chemical characteristics or the pore size due to hydrolysis.

The size of the macromolecule varies between different macromolecules; the smaller and more compact the macromolecule the easier it will be for the macromolecule to move through the pores of a given gel. Given a constant charge density, the rate of migration of a macromolecule is inversely proportional to the logarithm of its size.

For accurate and reproducible electrophoresis, a given type of macromolecule should preferably take on a single form in the gel. One difficulty with maintaining uniformity of the shape of proteins during gel electrophoresis is that disulfide bonds can be formed by oxidation of pairs of cysteine amino acids. Different oxidized forms of the protein then have different shapes and, therefore, migrate through the gel run with slightly different mobilities (usually faster than a completely reduced protein, since the maximum stokes radius and minimum mobility should occur with a completely unfolded form). A heterogeneous mixture of forms leads to apparent band broadening. In order to prevent the formation of disulfide bonds, a reducing agent such as dithiothreitol (DTT) is usually added to the samples to be run. The shape of DNA and RNA macromolecules is dependent on temperature. In order to permit electrophoresis on temperature-dependent DNA and RNA molecules in their desired form, separations are done at a controlled temperature.

The charge density of the migrating molecule is the third factor affecting its rate of migration through the gel—the higher the charge density, the more force will be imposed by the electric field upon the macromolecule and the faster the migration rate subject to the limits of size and shape. In SDS PAGE electrophoresis, the charge density of the macromolecules is controlled by adding sodium dodecyl sulfate (SDS) to the system. SDS molecules associate with the macromolecules and impart a uniform charge density to them, substantially negating the effects of any innate molecular charge. Unlike proteins, the native charge density of DNA and RNA is generally constant, due to the uniform occurrence of phosphate groups. Thus, charge density is not a significant problem in electrophoresis of DNA and RNA.

SDS PAGE gels are usually poured and run at basic pH. The most common PAGE buffer system employed for the separation of proteins is that developed by Ornstein (1) and modified for use with SDS by Laemmli (2). Laemmli, U.K. (1970) *Nature* 227, 680–686. The Laemmli buffer system consists of 0.375 M tris (hydroxy methyl) amino-methane (Tris), titrated to pH 8.8 with HCl, in the separating gel. The stacking gel consists of 0.125 M Tris, titrated to pH 6.8. The anode and cathode running buffers contain 0.024 M Tris, 0.192 M glycine, 0.1% SDS. An alternative buffer system is disclosed by Schaegger and von Jagow. Schaegger, H. and von Jagow, G., *Anal. Biochem.* 1987, 166, 368–379. The stacking gel contains 0.75 M Tris, titrated to pH 8.45 with

HCl. The separating gel contains 0.9 M Tris, titrated to pH 8.45 with HCl. The cathode buffer contains 0.1 M Tris, 0.1 M N-tris(hydroxymethyl)methylglycine (tricine), 0.1% SDS. The anode buffer contains 0.2 M Tris, titrated to pH 8.9 with HCl. For both of these systems Tris is the "common ion" which is present in the gel and in the anode and cathode buffers.

In the Laemmli system, the pH of the trailing phase in the stacking gel is about 8.9. In the separating gel, the trailing phase pH is about 9.7. At this pH, primary amino groups of proteins react readily with unpolymerized acrylamide, thiol groups are more subject to oxidation to disulfides, or reaction with unpolymerized polyacrylamide, than at neutral pH and acrylamide itself is subject to hydrolysis.

The shape of the DNA and RNA macromolecules is also dependent on a fourth important factor, temperature. The temperature-dependent shape of DNA and RNA is caused by the interaction of two macromolecules containing complementary sequences and the interaction of complementary sequences in a single macromolecule. Some techniques require that the DNA remain in its double-stranded form. Typically, such separations are done in Tris borate ethylene diamine tetra-acetic acid (TBE) buffer, consisting of 0.09 M Tris, 0.09 M boric acid, and 0.002 M ethylene diamine tetra-acetic acid (EDTA) on either polyacrylamide or agarose gels. In general, these separations are done at lower temperatures to maintain the double-stranded structure. In the absence of denaturants, DNA's and RNA's structure is fairly stable and not significantly affected by temperature.

In other techniques, dissociation of the two DNA strands (known as "melting") is utilized to effect the separation. Such methods require careful temperature control in order to produce a consistent separation. One method, non-isotopic single-strand conformational polymorphism ("Cold SSCP"), utilizes a dissociative sample buffer with heat to melt the strands, a TBE buffer, and a polyacrylamide gel. In Cold SSCP, temperatures of 4 to 35° C. are used to allow variable-conformation renaturation to occur between mutant strands, and temperature changes of only a few degrees can significantly alter the number of mutants seen. See Hongyo, et al., *Nucleic Acids Research*, 21, 3637 (1993). Another method, employed in DNA sequence analysis, typically utilizes TBE buffers containing 6 to 8 M urea and/or 2 to 12 M formamide, and elevated temperatures. It is important that the temperature remain high enough—typically 45 to 55° C.—to maintain fully melted DNA or RNA. Gels are usually polyacrylamide and sometimes substituted acrylamide polymers. For example, certain alkyl-substituted polyacrylamide gels are described in Shoor et al., U.S. Pat. No. 5,055,517.

These DNA and RNA separation methods are characterized by the use of continuous buffer systems, which use the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber, and the cathode chamber. These buffers usually are comprised of Tris and boric acid with EDTA added to inhibit hydrolytic enzyme activity. The TBE buffer system typically does not provide good stability when used in pre-cast gels, made and stored for periods of weeks at 4° C. The polymer tends to break down, generating a fixed charge which leads to distortion particularly at the cathode end of the gel where resolution is especially important. Urea also tends to break down under alkaline pH at 4° C. When large concentrations of urea are present, the ionic breakdown products can be present at a large enough concentration to disrupt the separation and cause loss of resolution.

Other buffer systems for DNA and RNA separations employ Tris/acetate, Tris/phosphate, and Tris/glycylglycine. While these buffer systems may be formulated near pH 7, the pK_a of Tris causes them to shift to an alkaline pH during electrophoresis especially near the cathode. The applicants have found that the polyacrylamide and urea tend to break down during electrophoresis for DNA sequencing due to the high temperatures (50° C.) employed for several hour runs when Tris is used as the buffering base. This breakdown leads to higher current and lower resolution than might be obtained with a neutral pH buffer system, so that the DNA sequence read length is reduced and read errors are increased.

The need for uniformity and predictability is magnified in precast electrophoresis gels which are manufactured by an outside vendor and then shipped to the laboratory where the electrophoresis will be performed. Precast gels must control the properties discussed above and they must be able to maintain this control throughout shipping and storage. The shelf life of many precast gels is limited by the potential for hydrolysis of acrylamide and/or buffer constitution during storage at the high pH of the gel buffer.

It is a disadvantage of a high pH gel that the polyacrylamide gel is subject to degradation by hydrolysis and has a limited shelf-life.

It is a further disadvantage of a high pH gel that proteins react readily with unpolymerized acrylamide which may interfere with subsequent analysis of the protein such as peptide sequencing.

It is a still further disadvantage of a high pH gel that thiol groups are subject to oxidation to disulfides causing a decreased resolution of separated macromolecules.

It is a further disadvantage of a high pH gel that buffer constituents such as urea break down readily.

SUMMARY OF THE INVENTION

It is an object of this invention to produce a neutral gel system that reduces protein reaction with unpolymerized acrylamide thereby enhancing yield and resolution.

It is a further object of this invention to produce a neutral gel system that prevents formation of disulfides from free thiol groups thereby enhancing yield and resolution.

It is also an object of this invention to produce a neutral gel system that reduces degradation of the polyacrylamide gel by hydrolysis thereby increasing the stability of a gel during electrophoresis and the useful shelf-life of a precast gel, and better resolution.

It is also an object of this invention to produce a neutral gel system that reduces breakdown of buffer constituents, such as urea.

In accordance with this invention, applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Applicants also describe a gel and buffer system wherein storage of the gel and subsequent electrophoresis of macromolecules (such as DNA, RNA, polypeptides and proteins) occurs at neutral pH. The above and other objects and advantages of the present invention will be apparent upon consideration of the following detailed description.

DETAILED DESCRIPTION OF THE INVENTION

Applicants describe a gel and buffer system wherein separation occurs at neutral pH and proteins remain completely reduced. Advantageously, at this neutral pH, primary amino groups of proteins react less readily with unpolymerized acrylamide because protonation of protein amino

groups greatly reduces their reactivity to acrylamide or other related blocking agents. Furthermore, at this neutral pH, thiol groups are less subject to oxidation than at higher pH and polyacrylamide itself is less subject to hydrolysis.

The result is a gel system with improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers without reducing agents and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance. An additional benefit is that a single gel recipe, using the same buffer for the stacking and separating gels, can be used with two different running buffers to give two separation systems. Using this feature, an 8% gel, for example, can cover a protein separation range of 2 to 200 kDa.

In one embodiment of this invention a polyacrylamide gel of between about 3% and about 25% (% T) acrylamide is polymerized using from about 1% to about 6% crosslinker (% C) using a gel buffer comprising a primary organic amine or substituted amine with a pK_a near neutrality, titrated with approximately half as much HCl (on a molar basis), so that the pH of the buffer is approximately neutral. In a preferred embodiment the gel is polymerized using from about 2% to about 5% crosslinker (% C) using a gel buffer comprising bis-(2-hydroxyethyl) iminotris (hydroxymethyl) methane (Bis-Tris) titrated with HCl. Different separation characteristics can be obtained by running the gel with either a 3-(N-morpholino) propanesulfonic acid (MOPS) or 2-(N-morpholino) ethanesulfonic acid (MES), buffer. 2 mM to 10 mM thioglycolic acid (TGA) or 2 mM to 10 mM sodium bisulfite is added to the running buffer to maintain a reducing environment in the gel during electrophoresis.

Applicants also describe another gel and buffer system for separation of macromolecules (including DNA, RNA, polypeptides and proteins) wherein separation occurs at neutral pH. This gel and buffer system may be a discontinuous or continuous buffer system, but is particularly useful in a continuous system. A continuous buffer system is one using the same buffer species and generally, but not necessarily, in the same concentrations in the gel, the anode chamber and the cathode chamber. This gel and buffer system permits higher resolution during electrophoresis when alkaline-labile compounds such as polyacrylamide and urea are present. This gel and buffer system also permits higher resolution when elevated temperatures are used. Advantageously, at this neutral pH, urea is less subject to hydrolysis. Furthermore, polyacrylamide itself is less subject to hydrolysis.

This gel and buffer system also possesses improved stability of the gel matrix and stock solutions. Gels prepared according to this system can be stored under refrigeration for over a year without loss of performance due to acrylamide hydrolysis. Also, stock buffers and stock gel solutions without polymerization initiator can be stored for at least several weeks at room temperature with no loss of performance.

In an embodiment of this gel and buffer system an electrophoresis gel is uniformly saturated with a gel buffer solution comprising a primary organic amine or substituted amine with a pKa near neutrality, titrated with approximately an equimolar amount of acid or zwitterionic compound, so that the pH of the buffer is between about pH 6 and pH 8, preferably between about pH 6.5 to pH 7.5, and most preferably 6.5 to 7.0. The electrophoresis gel may be any agarose or polyacrylamide gel. Preferably, the electrophoresis gel comprises between 3% and 25% (% T) acrylamide polymerized using from about 1% to about 6% cross linker (% C). More preferably, this polyacrylamide gel is polymerized using from about 2% to about 5% crosslinker (% C). Preferably, the amine comprises Bis-Tris or N-(2-hydroxyethyl) morpholine, and most preferably, Bis-Tris. Suitable acids and zwitterionic compounds are hydrochloric acid, tricine, acetic acid, piperazine-N,N'-bis(2-ethanesulfonic acid), 3-(N-morpholino)-propanesulfonic acid, 2-(N-morpholino)ethanesulfonic acid, N-(2-acetamido)-2-aminoethanesulfonic acid, 3-(N-morpholino)-2-hydroxypropanesulfonic acid, N-[tris(hydroxymethyl) methyl]-2-aminoethanesulfonic acid, N-(2-hydroxyethyl)-piperazine-N'-(2-ethanesulfonic acid), N,N-bis(2-hydroxyethyl)-2-aminoethanesulfonic acid, and 3-(N-tris (hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid. Tricine, 2-(N-morpholino)-ethanesulfonic acid, and piperazine-N,N'-bis(2-ethanesulfonic acid) are preferred for use in the buffer for a continuous gel and buffer system for separation of DNA and RNA because the resulting system has separation characteristics similar to the commonly used TBE gel systems. Tricine is most preferred for that use. Preferably, the gel buffer comprises Bis-Tris titrated with tricine.

In a gel and buffer system, current increases and migration rates decline as the performance of the gels decline. The increase in current has been attributed to alkaline-catalyzed hydrolysis of urea present at 36% to 42% concentration. Any breakdown in a neutral substance present at a large concentration, which produces a charged species will tend to disrupt the electrophoresis. This disruption arises from the extra current produced, which in turn increases joule heating without aiding the separation. In addition, a discontinuity arises from the anionic and cationic hydrolysis products forming in the gel that are not present in the cathode and anode buffers. Hydrolysis of gel buffer species or additives takes place independently from the gel matrix composition. The decrease in migration rate may be attributed to higher fixed charge in the gel caused by alkaline-catalyzed hydrolysis of the gel's polyacrylamide. The fixed charge leads to significant counter-flow of water, which can retard a macromolecule's migration rate. It has been found that problems of gel instability producing lower resolution, increased current, decreased migration rates can be solved with gels buffered near neutrality and with buffer substances having a pK_a near neutrality. Such buffering systems improve the performance of fresh or pre-cast polyacrylamide gels, and fresh or pre-cast gels containing alkaline-labile materials, such as urea or formamide, even when the gels are made with base-stable polymers.

The inventors also have discovered the value of using different buffer substances in the cathode, gel, and anode buffers. A group of substitutions relating to cost and throughput have been discovered. The anionic substance used in the gel or the cathode buffer need not be present in the anode buffer since the anions do not migrate out of the anode buffer. In fact, the use of chloride or other strong acids in the anode buffer serves to increase the conductance of the buffer, thereby increasing the net voltage drop across the gel and decreasing run times. Such acids are also typically much less expensive as compared to those employed in the cathode buffer. Similarly, the base used to adjust the pH of the cathode buffer need not be the same as that used in the gel. At a neutral pH, sodium hydroxide, Tris, and other organic bases with a basic pK_a have a higher conductance and often lower cost than Bis-Tris or other bases with a pK_a near neutrality. Using sodium or Tris salts in the cathode buffer

will also decrease the gel run times. Often, the anode and cathode buffers are used at a higher concentration than in the gel, further increasing their conductance and decreasing gel run times. Thus, using different, more conductive anode and cathode buffer species than in the gel buffer increases throughput and decreases costs.

It was also found that Tris or Bis-Tris may be used in the anode buffer with no visible effect on the separation quality. Because of its higher pK_a, Tris gradually infiltrates the anode end of the gel increasing that region's conductance, causing the voltage drop to fall locally. Thus, the macromolecules near the anode slow down and the separation compresses, while the macromolecules near the cathode experience a higher voltage drop increasing their migration and relative separation. This effect of Tris actually improves the resolution of macromolecules at the cathode end of the gel where it is most needed. Tris is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris and can improve read lengths.

The preferred embodiment of this invention uses Tris chloride in the anode buffer, the sodium or Tris salt of the acid or zwitterionic compound in the cathode buffer, and Bis-Tris as the gel buffer amine. For protein and polypeptide separations, the most preferred cathode buffers are sodium or Tris salts of MOPS and MES, combined with a Bis-Tris chloride gel buffer. For DNA and RNA separations, the most preferred cathode buffers are sodium or Tris salts of tricine, combined with a Bis-Tris tricine EDTA running buffer. When the buffer chambers are small, the most preferred molar concentrations of the cathode and anode buffers are five times that present in the gel buffer. These buffer systems provide the benefits of a neutral pH gel during both storage and running, the least cost, and the fastest run times.

These and other embodiments can be understood by reference to the following illustrative and comparative examples.

EXAMPLES

Tris, Bis-Tris, MES, tricine, MOPS and Piperazine-N,N'-bis(2-ethanesulfonic acid) (PIPES) were purchased from Sigma (St. Louis, Mo.) or Research Organics (Cleveland, Ohio). Thioglycolic acid (TGA), dithiothreitol (DTT) and beta-mercaptoethanol (BME) were from Sigma. All other chemicals were reagent, "ultra pure" or "electrophoresis grade" from standard sources.

In Example 1 through 6, gels were cast in 1 mm thickness mini-gel cassettes from NOVEX (San Diego Calif.) and run in an X-Cell minicell. The Bis-Tris separating gel and stacking gels were prepared from a 30% T/2.5% C acrylamide/BIS stock solution and a 7× Bis-Tris stock solution (2.5M Bis-Tris, 1.5M HCl, pH 6.5). To prepare the separating gel, the stock solutions were blended with ultra pure water to a final concentration 8% T, 0.357M Bis-Tris, to which was added 0.2 ul/ml N,N,N',N'-tetra-methyl-ethylene-diamine (TEMED). After degassing, 2.0 ul/ml of a 10% solution of ammonium persulfate (APS) was added, the gel was immediately poured into the cassette then overlaid with water. Polymerization was allowed to proceed for at least 30 minutes at room temperature (RT), the water was removed and a 4% stacking gel applied. The stacking gel was prepared in the same fashion as the separating gel, except that the final concentration obtained was 4% T, the TEMED concentration was increased to 0.4 ul/ml and the APS-solution increased to 5.0 ul/ml. MOPS running buffer consisted of 50 mM MOPS, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. MES running buffer consisted of 50 mM MES, 50 mM Bis-Tris (or Tris), 0.1% SDS, 1 mM EDTA. Sample buffer (2×) consisted of 0.25 M Bis-Tris, 0.15 M HCl, 10% (w/v). Glycerol, 2% SDS, 1 mM EDTA, 0.03% Serva Blue G, and 200 mM DTT. Samples containing a set of protein standards were heated for 15 min at 70 degrees before application. Bovine serum albumin (BSA), chicken egg ovalbumin, alkylated insulin A and B chain, soybean trypsin inhibitor, and bovine erythrocyte carbonic anhydrase were included in the standard. Sample volume was 5 ul in all cases.

Example 1

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the absence of a reducing agent. The resulting separation pattern was very similar to that obtained on an 8% Tris/glycine gel (Laemmli), with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The BSA band was somewhat diffuse and shifted toward the anode. The Ovalbumin band was also somewhat diffuse.

Example 2

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of TGA in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without TGA.

Example 3

The protein standards were separated on an 8% Bis-Tris/Cl gel with MOPS running buffer in the presence of sodium bisulfite in the cathode buffer. Again, the separation pattern was very similar to that obtained on an 8% Tris/glycine (Laemmli) gel, with proteins 20,000 and smaller remaining in the stack along with the tracking dye. The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the proteins BSA and Ovalbumin compared to the gel run without sodium bisulfite.

Example 4

The protein standards were separated on an 8% Bis-Tris/Cl gel with MES running buffer in the absence of a reducing agent. The protein separation was very similar to that obtained from an 12% Tris/tricine (Schaegger) gel. All proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). When the gel is run without TGA, soybean trypsin inhibitor had a more prominent doublet.

Example 5

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of TGA in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM TGA, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Example 6

The protein standards were separated on an 8% Bis-Tris/Cl gel with Bis-Tris/MES running buffer in the presence of

sodium bisulfite in the cathode buffer. Again, all proteins were resolved from the stack including insulin A and B chain (3500 and 2500 daltons, respectively). The presence of the reducing agent, 5 mM sodium bisulfite, in the cathode buffer provided for better resolution of the protein soybean trypsin inhibitor. Carbonic anhydrase ran as a tight, sharp band under all conditions tested.

Although MES and MOPS were selected as desirable running buffers for protein separation because the resulting system has separation characteristics similar to the commonly used Laemmli and Schaegger gel systems, it was found that a range of buffers are suitable for use in this system. Among the additional buffers giving good results were [N-(2-acetamido)]-2-aminoethanesulfonic acid (ACES), 3-[N-morpholino]-2-hydroxypropanesulfonic acid (MOPSO), N-[Tris-(hydroxymethyl)methyl]-2-aminoethanesulfonic acid (TES), N,N-bis(2-hydroxyethyl)-2-aminoethanesulfonic acid (BES), N-(2-hydroxyethyl)-piperazine-N'-(2-ethanesulfonic acid) (HEPES), and 3-(N-Tris-(hydroxymethyl) methylamino)-2-hydroxypropanesulfonic acid (TAPSO).

All the proteins that exhibit some band broadening and/or mobility shifts when run in the absence of TGA or sodium bisulfite, have in common a composition that includes multiple cysteines (BSA, for instance, has 35 cysteines). On the other hand carbonic anhydrase, which always runs cleanly, has no cysteines. Moreover, if the reduced proteins are alkylated before running, they run as sharp homogeneous bands even in the absence of a reducing agent.

Cysteine-containing proteins appear to give generally sharper bands in the Laemmli system than the neutral system, when both are run with 100 mM mercaptoethanol or DTT in the sample buffer but without TGA in the running buffer. Since thiol oxidation is more favored as the pH increases, it would be expected that the higher pH of the Laemmli system would cause oxidation of disulfide to be at least as pronounced as it is in the neutral pH system. However, DTT and similar "neutral" thiol reducing agents are weak acids (with pK_a's around pH 8–9). Thus, at basic pH, these reducing agents migrate into the gel and, if present at sufficient concentration, provide some protection against oxidation of sulfhydryls. At a neutral separating pH, DTT from the sample buffer is in an uncharged form and will remain behind in the sample well. Thus, no reducing agent migrates into the gel.

To maintain proteins in a reduced form during electrophoresis at neutral pH, it was found advantageous to use a reducing agent that would migrate into the gel at neutral pH. Sodium bisulfite (2–10 mM) was found to maintain a reducing environment in the gel during electrophoresis. Fully reduced TGA (or similar negatively charged thiols) give similar results at comparable concentrations. However, partially oxidized TGA will promote partial oxidation of protein thiols. Because reduction (oxidation) of protein thiols will take place via disulfide interchange, the ratio of reduced to oxidized thiols in the protein will substantially reflect the ratio of reduced to oxidized thiols in the TGA. Conversely, sulfite oxidizes to sulfate, which does not participate in redox reactions under conditions found in the gel. Therefore, regardless of the sulfite/sulfate ratio in a partially oxidized preparation of sulfite, as long as sufficient sulfite remains, proteins will be protected against thiol oxidation.

It was also found that Tris could be substituted for Bis-Tris in the running buffer with no visible effect on the separation quality. Bis-Tris may be preferred where the protein will be intentionally modified post-separation. Bis-Tris is a tertiary amine and will not interfere with the protein modifying agents which react through primary amines. Tris, however, is the preferred choice for routine use, because it is available at significantly lower cost than Bis-Tris.

Example 7

A 14.7% T/5% C TBE urea gel was made in the following manner. To prepare the separating gel solution, a 30% acrylamide/1.6% bis-acrylamide stock solution (47.5 ml), and a 5x gel buffer stock solution containing 0.45 M Tris, 0.45 M boric acid, and 0.01 M EDTA, pH 8.18 (20 ml) were mixed with urea (36 g), TEMED (20 ul), and enough water was added to make 100 ml. The final solution pH was 8.87. It was degassed, a 10% ammonium persulfate solution ("10% APS") (12.8 ul) was added to 6.4 ml, and poured into a 1 mm thick mini-gel cassette from NOVEX (San Diego, Calif.). A comb-forming gel solution was made similarly, with the following differences: acrylamide/bis solution (12.7 ml), TEMED (50 ul), and no urea; to 1.0 ml of this solution was added 10% APS (0.1 Ml) and it was immediately poured on top of the separating gel solution. A 1 mm 10-well comb (NOVEX) was added, and the gels were allowed to polymerize for at least 30 minutes at room temperature. They were then run after storage in sealed pouches with 1x gel buffer containing 7M at different temperatures.

The gels were run fresh or after storage at either 4° C. or 35° C. Samples employed were a 10b oligo DNA standard (BRL, Bethesda, Md.) or an 18-mer custom-synthesized DNA fragment (Synthetic Genetics, San Diego, Calif.). Gels were run in an X-Cell mini-cell (NOVEX) at 180 volts for 80 minutes, using 1x gel buffer in both the anode and cathode chambers. Finally, the bands were visualized by treating with isle Stains-All solution (Sigma) for 15 minutes then destaining in 20% methanol for 10 minutes.

Compared to fresh gels, the gels stored at 4° C. showed a gradual loss of band sharpness and an increase in current during the electrophoresis. The loss of sharpness leads to less resolution between bands. After 2 weeks at 4° C., the band width had doubled as compared to fresh gel bands. When stored at 35° C. for 1 week, the gels ran with higher current but the dye front only migrated 80% as far in 80 minutes. The gel itself retained the stain, and the bands were fuzzy and indistinct. After three weeks, no bands could be seen and the gels were very fragile.

Example 8

Gels were prepared, stored, and run as described in Example 7, except that the 5x gel buffer was composed of 0.45 M Bis-Tris, 0.45 M tricine, and 0.01 M EDTA pH 7.27, the final gel solution pH was 7.70, and the running buffer was 0.05 M Tris, 0.05 M tricine, 0.001 M EDTA. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to 3 weeks at 35° C. or for several months at 4° C.

Example 9

Gels were prepared, stored, and run as described in Example 7, except that the 5x gel buffer was composed of 0.125 M N-(2-hydroxyethyl) morpholine (HEM), 0.083 M acetic acid, and 0.002 M EDTA pH 7.0, and the final gel solution pH was 7.21. These gels showed no significant change in band sharpness, running current, or migration distances when stored for up to three weeks at 35° C. or for several months at 4° C. However, the gels turned yellow on storage at 35° C.

Example 10

Mini-DNA sequencing gels were prepared from the same separating gel solution as described in Example 7, except

that only 23.3 ml of acrylamide/bis solution was employed, the urea was increased to 42 g, and the TEMED was increased to 50 ul. It was used without degassing by adding 10% APS (50 ul) to 10 ml of the solution, and pouring between 11 cm wide by 22 cm long thick glass plates with 0.25 mm spacers. The gels were allowed to polymerize for 60 minutes at room temperature, then run the same day.

Samples employed were an M-13 DNA sequencing reaction prepared with S^{35}-label using a USB Sequenase kit, version 2, (United States Biochemicals, Cleveland, Ohio). They were run in a custom-made DNA sequencing chamber at 15 watts (about 50° C.). Finally, the bands were visualized by autoradiography. The gels had a read length of 120 bases with a 5% error rate (95% accuracy).

Example 11

Gels were prepared and run as in Example 10, except that the 5× gel buffer was composed of 0.5 M Bis-Tris, 0.84 M tricine, and 0.01 M EDTA pH 7.2 and the final gel solution pH was 7.50. The gels had a read length of 137 bases with a 1.5% error rate (98.5% accuracy).

Example 12

The separating gel solution was prepared as in Example 7, except that a SoaneGel SQ solution (a solution of substituted acrylamide and substituted bis-acrylamide cross-linkers, available from Soane Biosciences Inc., Hayward, Calif.) was used for the polymer at 6% T, and the TEMED was increased to 88 ul. After initiation of the gel solution (40 ml) with 10% APS (200 ul), the gels were poured in plates with 0.35 mm spacers for an ABI Model 377 DNA Sequencer (Applied Biosystems Division of Perkin Elmer Corp., Foster City, Calif.), and allowed to polymerize at room temperature for 2 hours. The gels were loaded with a PGEM sequencing reaction and run with 1× TBE buffer at 30 V/cm, generating 55° C. They had a read length of 815 bases; at 550 bases the error rate was 1.5% (98.5% accuracy).

Example 13

Gels were prepared and run as in Example 12, except that the 5× gel buffer was composed of 0.5 M Bis-Tris, 0.84 M tricine, and 0.01 M EDTA pH 7.2, and the final gel solution pH was 7.5. The gels were run with 1× gel buffer at 30 V/cm, generating 55C., and had a read length of 866 bases; at 550 bases the error rate was 1.1% (98.9% accuracy).

Although the invention has been explained in relation to its preferred embodiments, it is to be understood that various modifications thereof will become apparent to those skilled in the art. The foregoing disclosure is not intended or to be construed to limit the present invention, or to otherwise exclude any such other embodiments, adaptions, variations and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

We claim:

1. A gel, comprising:

between 8 and 25 (wt/vol)% acrylamide; and

a gel buffer having a pH between 6 and 8, wherein said gel buffer comprises bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane,

wherein said gel is an electrophoresis separating gel.

2. The gel of claim 1, wherein said gel is precast.

3. The gel of claim 1, said gel having a shelf life that is greater than or equal to one month when said gel is stored under refrigeration.

4. The gel of claim 3, said gel having a shelf life of at least one year.

5. The gel of claim 1, wherein said pH is based on titration with hydrochloric acid.

6. The gel of claim 1, wherein said gel buffer has a pH of between 6.5 and 7.5.

7. The gel of claim 1, wherein said gel is has a pH of about 7.

8. The gel of claim 1, further comprising about 10 (wt/vol) percent acrylamide.

9. The gel of claim 1, further comprising about 12 (wt/vol) percent acrylamide.

10. A gel electrophoresis system, comprising:

a separating gel including acrylamide and a bis(2-hydroxyethyl) iminotris (hydroxymethyl) methane gel buffer having a pH between 6 and 8;

an electrophoresis unit; and

at least one running buffer.

11. The gel electrophoresis system of claim 10, wherein said electrophoresis unit is a mini-gel unit.

12. The gel electrophoresis system of claim 10, wherein said at least one running buffer is selected from the group comprising MES and MOPS.

13. The gel electrophoresis system of claim 10, wherein said separating gel has a pH of about 7.

14. The gel electrophoresis system of claim 10, wherein said separating gel has a shelf life of at least one year.

15. The gel electrophoresis system of claim 10, further comprising a plurality of separating gels.

16. The gel electrophoresis system of claim 10, wherein said separating gel is between 3 and 25 (wt/vol) percent acrylamide.

17. The gel electrophoresis system of claim 16, wherein said separating gel is about 10 (wt/vol) percent acrylamide.

18. The gel electrophoresis system of claim 16, wherein said separating gel is about 12 (wt/vol) percent acrylamide.

* * * * *