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METHOD FOR LYSING CELLS

5 Background of the Invention

Increasing attention has been focused on the delivery of DNAs as therapeutic agents (i.e., DNA gene therapy) for the treatment of genetic diseases and for genetic immunization. Because of safety concerns with using potentially infectious viruses, researchers have been studying alternatives to viruses, using naked DNA or other non-viral methods of DNA delivery. One of the most promising non-viral methods in DNA therapy is the use of cationic lipids as delivery vehicles (Felgner, *Proc. Natl. Acad. Sci.*, 84:7413-7417, 1987). The cationic lipids adsorb to negatively charged DNA and facilitate entry of the DNA into target cells. Successful delivery of genes via lipids into airway epithelia of rodents (Hyde, *Nature*, 362:250-255, 1993) have been reported. If future 'gene therapy' proves to be effective, huge quantities of plasmids or appropriate DNA will be needed. However, current methods for isolating limited amounts of DNA may impede progress in this field.

Generally, the first step in making copies of a gene of interest starts with inserting the appropriate portion of DNA into plasmids which are then replicated in "host cells". Host cells include eukaryotic and prokaryotic cells. Once a sufficient amount of plasmids are produced in the host cells, the host cells are lysed to release the internally replicated plasmids.

Numerous mechanical methods for lysing cells have been developed and published. They include pressure, cavitation, sonic or ultrasonic waves, mechanical shaking with abrasives or grinding (Sadeva, *Biopharm* 7(2):26-36, 1994). However, few of these methods are suitable for recovery of DNA or other shear sensitive materials from cells. Chemical

(Foster, *Biotechnol.* 10:273-277, 1992) and enzymatic (Andrews and Asenjo, *Tibtech.* 5:273-277, 1987) treatments, are more gentle and can be used for the recovery of shear sensitive products, such as DNA.

5 Generally, methods of plasmid isolation involve lysing the plasmid-containing cells with alkali (i.e. caustics) or enzymes in a test tube by gently inverting the tube several times. After the cells have been lysed, the cell lysate is mixed with a precipitating solution in a test tube by again gently
10 inverting the test tube several times. The object is to precipitate contaminating cell components, e.g. genomic DNA, proteins, and protein-nucleic acid complexes, leaving the plasmids in solution. The plasmids can then be separated from the precipitate by centrifugation. While this approach
15 can be used for small scale isolation, it is not practical for large scale production because the lysate is extremely viscous after the release of genomic DNA. Although, effective and gentle mixing of large quantities of viscous material can be achieved by using special agitators/mixers (e.g., planetary
20 mixers), these types of equipment are expensive and are not easily automated. In addition, the time of exposure of each plasmid to alkali in the large volume of solution is difficult to control and can vary a great deal and this may affect plasmid quality. Furthermore, it is crucial to handle the lysate very
25 gently because any sheared genomic DNA may contaminate the sample and render later plasmid purification extremely difficult.

30 A need exists to develop an effective, economical, and automatable method for isolating high quality plasmids on a large scale to meet the future demand.

Summary of the Invention

35 This invention relates to the use of static mixers in a novel manner, such as to rapidly lyse large amounts of cells. The lysis method comprises simultaneously flowing a

cell suspension and a lysis solution through a static mixer, wherein the cells exit the static mixer lysed. A key advantage of the present invention is that multi-liter amounts of solution containing multi-gram amounts of cells
5 can be lysed rapidly, making large scale biological procedures involving cell lysis feasible.

In another aspect of the present invention, the invention relates to a rapid method for precipitating cell components, protein, and nucleic acids from a cell lysate or
10 other solution to be precipitated, using a static mixer. The method comprises simultaneously flowing a cell lysate or other protein-containing solution and a precipitating solution through a static mixer, wherein the lysate or protein solution exits the static mixer with its precipitable
15 components precipitated.

In another aspect of the present invention, the invention relates to a method where the two above-mentioned methods are combined by using static mixers in series, i.e., by first lysing the cells through a first static
20 mixer and then precipitating the cell lysate through a second static mixer.

In another aspect of the present invention, the invention relates to a method for releasing intact usable plasmids from plasmid-containing cells, comprising
25 simultaneously flowing a solution containing the plasmid-containing cells and a lysate solution through a static mixer wherein the plasmid-containing cells exit the static mixer lysed and the plasmids released. In addition, the method of releasing a plasmid further includes a preliminary step,
30 prior to the lysing step, of simultaneously diluting the cells to be lysed to an optimal cell density by flowing the plasmid-containing cell suspension and a solution through a static mixer prior to simultaneously flowing the diluted cell suspension with a lysis solution through another static
35 mixer (i.e., a second static mixer) with the same results. Furthermore, this method can include the precipitation

step, explained above, where the cell lysate of the second static mixer is combined with a precipitating solution through a third static mixer.

5 **Brief Description of the Drawings**

Figure 1 is an illustration of the method of the present invention where cells are passed through a static mixer simultaneously with a lysis solution, the result being
10 that the cells exit the static mixer lysed.

Figure 2 is an illustration of the method of the present invention where a cell lysate (or protein solution) is passed through a static mixer simultaneously with a precipitating solution the result being that the cell lysate
15 (or protein solution) exits the static mixer precipitated.

Figure 3 is an illustration of the method of the present invention where cells are first passed through a static mixer simultaneously with a cell diluting solution, then the mixture exiting the first static mixer is passed
20 through a second static mixer along with a lysis solution, then that mixture is passed through a third static mixer simultaneously with a precipitating solution.

25 **Detailed Description of the Invention**

This invention is based upon the discovery that static mixers could be used to lyse cells containing plasmids, releasing the plasmids from the cells. The advantage of using such a device is that large volumes of cells can be gently and
30 continuously lysed in-line using the static mixer and that other static mixers could be placed in-line to accomplish other functions such as dilution and precipitation. This method greatly simplifies the process of isolating plasmids from large volumes of material such that plasmid DNA is not damaged by
35 the process. Previous methods of plasmid isolation involving caustic lysing and precipitation, which involved expensive and

specialized equipment, were not practical for large scale plasmid purification.

5 The method of the present invention can be used to lyse any type of cell (i.e., prokaryotic or eukaryotic) for any purpose related to lysing, such as releasing desired nucleic acids or proteins from target cells to be subsequently purified. In a preferred embodiment, the method of the present invention is used to lyse host cells containing plasmids to release plasmids.

10 The term "lysing" refers to the action of rupturing the cell wall and/or cell membrane of a cell which is in a buffered solution (i.e., cell suspension) through chemical treatment using a solution containing a lysing agent. Lysing agents include for example, alkali, detergents,
15 organic solvents, and enzymes. In a preferred embodiment, the lysis of cells is done to release intact plasmids from host cells. For purposes of the present invention the term "simultaneously" referring to the passage of substances through a static mixer, means that
20 the subject substances are passing through the static mixer at approximately the same time.

For purposes of the present invention the term "flowing" refers to the passing of a liquid at a particular flow rate (e.g., liters per minute) through the static mixer,
25 usually by the action of a pump. It should be noted that the flow rate through the static mixer is believed to affect the efficiency of lysis, precipitation and mixing.

Suitable static mixers useful in the method of the present invention include any flow through device referred
30 to in the art as a static or motionless mixer of a length sufficient to allow the processes of the present invention. For example, for the purpose of lysing cells, the static mixer would need to have a length which would provide enough contact time between the lysing solution and the cells to
35 cause the lysis of the subject cells during passage through the mixer. In a preferred embodiment, suitable static

mixers contain an internal helical structure which causes two liquids to come in contact with one another in an opposing rotational flow causing the liquids to mix together in a turbulent flow.

5 For purposes of the present invention the term "precipitating" refers to the action of precipitating proteins and other cell components from a solution through chemical precipitation using a solution containing a precipitating agent. Precipitating agents include sodium
10 dodecyl sulfate (SDS) and potassium acetate.

The term "plasmid" for purposes of the present invention include any type of replication vector which has the capability of having a non-endogenous DNA fragment inserted into it. Procedures for the construction of plasmids include
15 those described in Maniatis *et al.*, *Molecular Cloning, A Laboratory Manual, 2d, Cold Spring Harbor Laboratory Press* (1989).

In a preferred embodiment, illustrated in Figure 3, the method of releasing plasmids from plasmid-containing
20 host cells, comprises first simultaneously flowing the media containing the plasmid-containing host cells with a buffered solution through a static mixer i.e., the first static mixer. The mixture that exits the first static mixer is thereby equilibrated with the buffer. The buffered
25 mixture is then simultaneously flowed through a second static mixer along with a lysis solution which, while passing through the length of the static mixer, lyses the cells releasing the plasmid and cellular components. The cell lysate is then passed through a third static mixer along
30 with a precipitation buffer which precipitates most of the cellular components but not the plasmids.

EXEMPLIFICATION

35

Escherichia coli (*E. coli*) cells that had been grown in a nutrient medium to a high cell density, the culture was then diluted directly by flowing the cells through a 1/2" x 27", 32-element, Kenics static mixer (purchased from
5 Chemineer, N. Andover MA) along with a resuspending solution (50mM Tris/HCl, 10mM EDTA, 100 mg RNaseA/ml, pH 8.0) until the exiting cells had an optical density of 25-40 at 600nm, as read by a spectrophotometer.

10 The diluted cell suspension exiting the first static mixture was then flowed through a second static mixer (same type of mixer as above) along with a lysis solution (200mM NaOH, 1% weight/volume SDS,) at a rate of 100-1,300 ml/min. The cells exited the second static mixer
15 lysed (i.e., cell lysate).

The cell lysate exiting the second static mixer was then flowed through a third static mixer (same type as above) with a precipitating solution (2.6 M potassium acetate, pH 5.2) at a similar flow rate as passed through
20 the second static mixer. The exiting suspension contained precipitated *E. coli* genomic DNA, proteins, and insoluble debris and the soluble plasmids. About 45 liters of mixture was collected from the third static mixer and processed. Approximately 1 gram of plasmid was isolated
25 from this run.

All of the static mixers above were connected in series by tubing and the respective solutions were flowed or pumped through the static mixers by peristaltic pumps (Cole-Parmer, Chicago IL).
30

THE INVENTION CLAIMED IS:

1. A method of lysing cells, comprising simultaneously
5 flowing a cell suspension and a lysis solution through
a static mixer, wherein the cells exit the static mixer
lysed.
2. The method of claim 1 wherein the lysis solution is a
10 solution containing a lysis agent selected from the
group consisting of an alkali, a detergent, an organic
solvent, and an enzyme or a mixture thereof.
3. The method of claim 1 wherein the cells are plasmid-
15 containing cells.
4. A method of precipitating cellular components from a
20 solution, comprising simultaneously flowing a cell
lysate and a precipitating solution through a static
mixer, wherein the cellular components exit the static
mixer precipitated.
5. The method of claim 4 wherein the precipitating
25 solution is a solution containing a precipitating agent
selected from the group consisting of sodium dodecyl
sulfate and potassium acetate or a mixture thereof.
6. The method of claim 4 wherein the cell lysate
contains plasmids.
- 30 7. A method of releasing plasmids from plasmid-
containing cells, comprising simultaneously flowing a
suspension containing the plasmid-containing cells
and a lysis solution through a static mixer wherein
35 the plasmid-containing cells exit the static mixer
lysed and plasmids released from the cells.

8. The method of claim 7 wherein the lysis solution is a solution containing a lysis agent selected from the group consisting of an alkali, a detergent, an organic solvent, and an enzyme or mixture thereof.
- 5
9. A method of releasing plasmids from plasmid-containing cells, comprising:
- 10
- a. simultaneously flowing a suspension containing the plasmid-containing cells and a buffered solution through a first static mixer; and
- b. simultaneously flowing the product of step a) and a lysis solution through a second static mixer wherein the plasmid-containing cells exit the static mixer lysed and plasmids released
- 15
- from the cells.
10. The method of claim 9 wherein the lysis solution is a solution containing a lysis agent selected from the group consisting of an alkali, a detergent, an organic solvent, and an enzyme or mixture thereof.
- 20
11. A method of releasing plasmids from plasmid-containing cells, comprising:
- 25
- a. simultaneously flowing a suspension containing the plasmid-containing cells and a buffered solution through a first static mixer;
- b. simultaneously flowing the product of step a) and a lysis solution through a second static mixer wherein the plasmid-containing cells exit the static mixer lysed and the plasmid released
- 30
- into the lysate; and
- c. simultaneously flowing the product of step b) through a third static mixer with a precipitating solution wherein the cellular components exit the static mixer precipitated, leaving the
- 35
- plasmid in solution.

12. The method of claim 11 wherein the lysis solution is
a solution containing a lysis agent selected from the
group consisting of an alkali, a detergent, an organic
solvent, and an enzyme or mixture thereof.
13. The method of claim 11 wherein the precipitating
solution is a solution containing a precipitating agent
selected from the group consisting of sodium dodecyl
sulfate and potassium acetate or mixture thereof.
14. A method of releasing plasmids from plasmid-
containing cells, comprising:
- a. simultaneously flowing a suspension containing
the plasmid-containing cells and a lysis solution
through a first static mixer wherein the
plasmid-containing cells exit the static mixer
lysed and the plasmid released; and
 - b. simultaneously flowing the product of step a)
through a second static mixer with a
precipitating solution wherein the product of
step a) exits the static mixer precipitated and
the plasmid soluble.
15. The method of claim 14 wherein the lysis solution is
a solution containing a lysis agent selected from the
group consisting of an alkali, a detergent, an organic
solvent, and an enzyme or mixture thereof.
16. The method of claim 14 wherein the precipitating
solution is a solution containing a precipitating agent
selected from the group consisting of sodium dodecyl
sulfate and potassium acetate or mixture thereof.

35

FIGURE 1

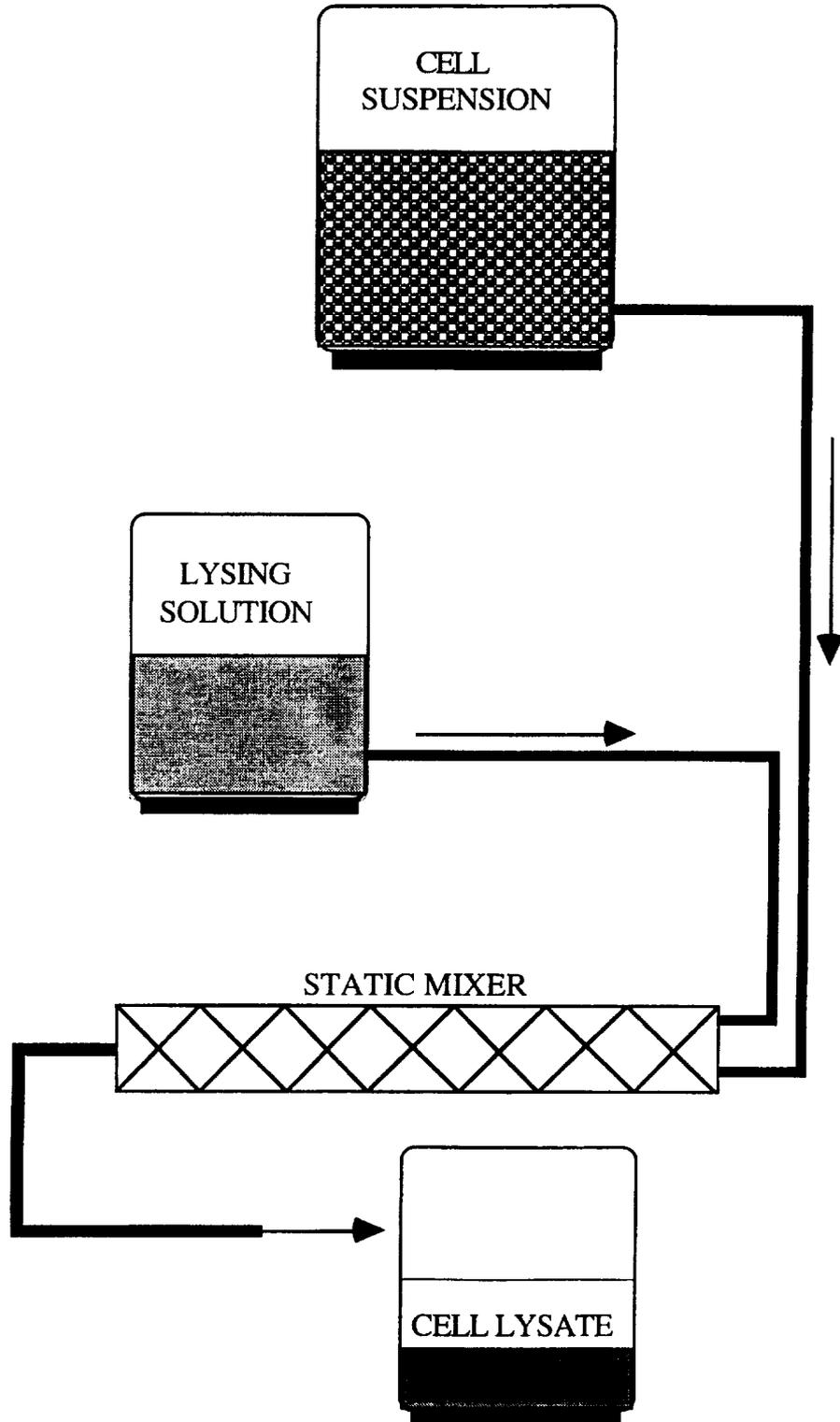


FIGURE 2

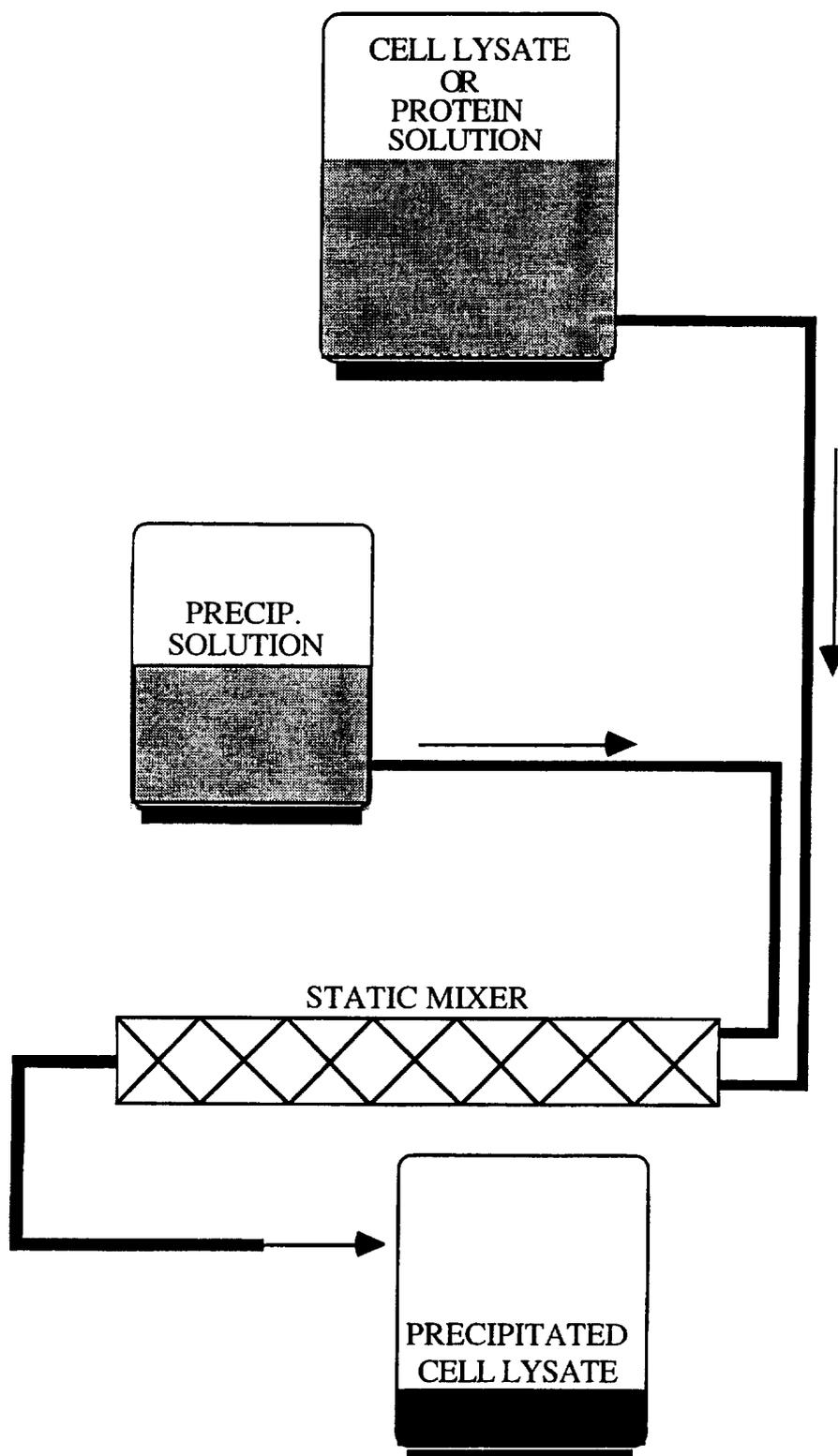
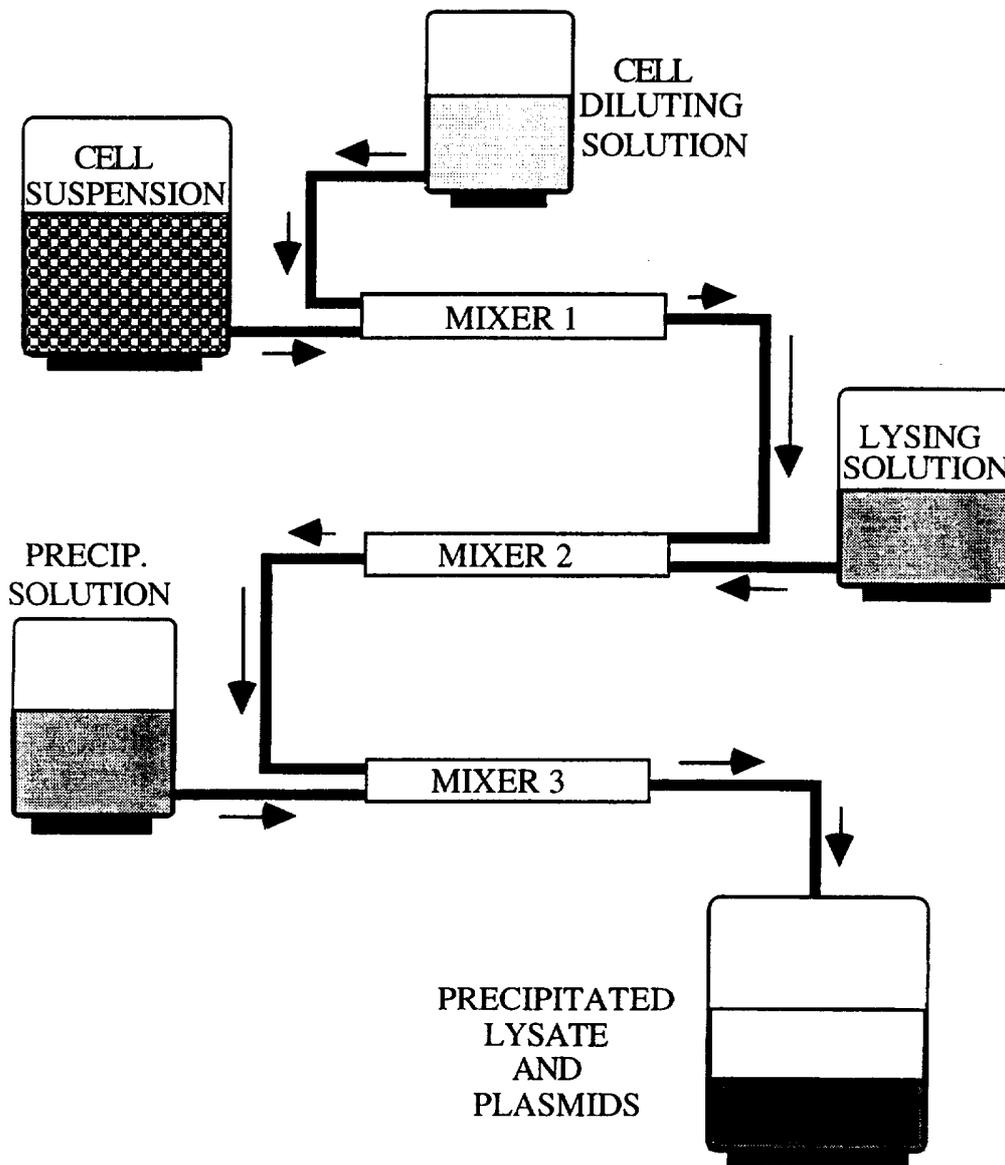


FIGURE 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/16843

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) : C12N 1/06 US CL : 435/259, 320.1, 287 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 435/259, 320.1, 287 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched KIRK-OTHMER Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) APS, CAS ONLINE DIALOG, MEDLINE, WPIDS search terms: lysis, lysing, static mixer, plasmid?, recover?		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	Journal of Chemical Technology and Biotechnology, Volume 54, issued 1992, Papamichael et al., "Continuous Aqueous Phase Extraction of Proteins: Automated Processing and Recycling of Process Chemicals", pages 47-55, especially page 48.	1-6 ----- 7-16
X --- Y	US, A, 4,462,940 (HANISCH et al.) 31 July 1984, column 10, lines 20-38.	1-3, 5-8 ----- 4-6, 10-16
Y	US, A, 4,900,677 (HEWITT) 13 February 1990, column 9, lines 21-60.	1-16
Y	US, A, 5,208,160 (KIKYOTANI et al.) 04 May 1993, Example 5 and comparative Example.	1-16
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* *A* *E* *L* *O* *P*	Special categories of cited documents: document defining the general state of the art which is not considered to be part of particular relevance earlier document published on or after the international filing date document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	*T* *X* *Y* *G* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
Date of the actual completion of the international search 11 APRIL 1996	Date of mailing of the international search report 29 APR 1996	
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,096,818 (DEBONVILLE) 17 March 1992, Example 1.	1-16
Y	US, A, 4,997,932 (REARDON et al.) 05 March 1991. See whole document, in particular, column 6, lines 5-19.	1-16
X	US, A, 4,450,103 (KONRAD et al.) 22 May 1984. See entire document, especially Example 3.	1-3, 7-10
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Y		4-6, 11-16
Y	Enzyme and Microbial Technology, Volume 6, number 7, issued 06 July 1984, Veide et al., "Continuous extraction of beta-D-galactosidase from Escherichia coli in an aqueous two-phase system: effects of biomass concentration on partitioning and mass transfer, pages 325-330, especially page 326.	1-16
Y	RODRIGUEZ ET AL., 'RECOMBINANT DNA TECHNIQUES: AN INTRODUCTION" published 1983 by The Benjamin/Cummings Publishing Company, Inc., (CA), see pages 37-46, especially, pages 45-46.	1-16