(54) Title: METHODS FOR GENERATING STABLY LINKED COMPLEXES COMPOSED OF HOMODIMERS, HOMOTE-TRAMERS OR DIMERS OF DIMERS AND USES

a) DDD1:

NH2-

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRL
REARA-*COOH* (SEQ ID NO:1)

b) DDD2:

NH2-

CGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTR
LREARA-*COOH* (SEQ ID NO:2)

(57) Abstract: The present invention concerns methods and compositions for stably tethered structures of defined compositions, which may have multiple functionalities and/or binding specificities. Particular embodiments concern homodimers comprising monomers that contain a dimerization and docking domain attached to a precursor. The precursors may be virtually any mole-cule or structure, such as antibodies, antibody fragments, antibody analogs or mimetics, aptamers, binding peptides, fragments of binding proteins, known ligands for proteins or other molecules, enzymes, detectable labels or tags, therapeutic agents, toxins, pharmaceuticals, cytokines, interleukins, interferons, radioisotopes, proteins, peptides, peptide mimetics, polynucleotides, RNAi, oligosaccharides, natural or synthetic polymeric substances, nanoparticles, quantum dots, organic or inorganic compounds, etc. Other embodiments concern tetramers comprising a first and second homodimer, which may be identical or different. The disclosed methods and compositions provide a facile and general way to obtain homodimers, homotetramers and heterotetramers of virtually any functionality and/or binding specificity.

METHODS FOR GENERATING STABLY LINKED COMPLEXES COMPOSED OF HOMODIMERS, HOMOTETRAMERS OR DIMERS OF DIMERS AND USES

BACKGROUND OF THE INVENTION

[0001] Man-made agents that incorporate multiple copies of both targeting and effector moieties are highly desirable, as they should provide more avid binding and confer enhanced potency. Although recombinant technologies are commonly applied for making fusion proteins with both targeting and effector domains, multimeric structures that comprise the same or different monomeric components to acquire multivalency or multifunctionality may be obtained only with judicious applications of conjugation chemistries.

[0002] For agents generated by recombinant engineering, problems may include high manufacturing cost, low expression yields, instability in serum, instability in solution resulting in formation of aggregates or dissociated subunits, undefined batch composition due to the presence of multiple product forms, contaminating side-products, reduced functional activities or binding affinity/avidity attributed to steric factors or altered conformations, etc. For agents generated by various methods of chemical cross-linking, high manufacturing cost and heterogeneity of the purified product are two major limitations.

[0003] Thus, there remains a need in the art for a method of making multivalent structures of multiple specificities or functionalities in general, which are of defined composition, homogeneous purity, and unaltered affinity, and can be produced in high yields without the requirement of extensive purification steps. Furthermore, such structures must also be sufficiently stable in serum to allow in vivo applications. A need exists for stable, multivalent structures of multiple specificities or functionalities that are easy to construct and/or obtain in relatively purified form.

SUMMARY OF THE INVENTION

[0004] The present invention discloses a platform technology for generating stably tethered structures that may have multiple functions or binding specificities or both, and are suitable for *in vitro* as well as *in vivo* applications. In one embodiment, the stably tethered structures are produced as a homodimer of any organic substance, which can be proteins or non-proteins. The homodimer, referred to as a_2 hereafter, is composed of two identical subunits linked to each other via a distinct peptide sequence, termed the dimerization and docking

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domain (DDD), which is contained in each subunit. The subunit is constructed by linking a

DDD sequence to a precursor of interest by recombinant engineering or chemical conjugation

via a spacer group, resulting in a structure that is capable of self-association to form a dimer.

Representative a_2 constructs made with the DDD sequence referred to as DDD1 (Figure 1a,

SEQ ID NO:1) are described in Examples 2 and 3.

[0005] In another embodiment, the stably tethered structures are produced predominantly as a

homotetramer of any organic substance, which can be proteins or non-proteins. The

homotetramer, referred to as a_4 hereafter, is composed of two identical a_2 constructs made

with the DDD sequence referred to as DDD2 (Figure 1b, SEQ ID NO:2), which is contained

in each of the four subunits. Five such a_4 constructs are described in Examples 4 and 5.

[0006] In yet another embodiment, the stably tethered structures are produced as a hybrid

tetramer from any two distinct a_4 constructs. The hybrid tetramer, referred to as $a_2a'_2$

hereafter, is composed of two different a_2 constructs derived from respective a_4 constructs.

Three such $a_2a'_2$ constructs are described in Example 6. In other embodiments, fusion

proteins that are single-chain polypeptides comprising multiple domains, such as avimers

(Silverman et al., Nat. Biotechnol. (2005), 23: 1556-1561) for example, may serve as

precursors of interest to increase the valency, functionality, and specificity of the resulting a_2,

a_4 and $a_2a'_2$ constructs, which may be further conjugated with effectors and carriers to

acquire additional functions enabled by such modifications.

[0007] Numerous a_2, a_4 and $a_2a'_2$ constructs can be designed and produced with the disclosed

methods and compositions. For example, at least 7 types of protein- or peptide-based

constructs as listed below are envisioned:

Type 1:   A bivalent a_2 construct composed of two Fab or scFv fragments derived from
            the same mAb. See Table 1 for selected examples.

Type 2:   A bivalent a_2 construct composed of two identical non-immunoglobulin
            proteins. See Table 2 for selected examples.

Type 3:   A tetravalent a_4 construct composed of four Fab or scFv fragments derived
            from the same mAb. See Table 3 for selected examples.

Type 4:   A tetravalent a_4 constructs composed of four identical non-immunoglobulin
            proteins. See Table 4 for selected examples.

Type 5:   A bispecific tetravalent $a_2a'_2$ construct composed of two Fab or scFv
            fragments derived from the same mAb and two Fab or scFv fragment derived
            from a different mAb. See Table 5 for selected examples.

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Type 6:   A multifunctional $a_2a'_2$ constructs composed of two Fab or scFv fragments

derived from the same mAb and two identical non-immunoglobulin proteins.

See Table 6 for selected examples.

Type 7:   A multifunctional $a_2a'_2$ constructs composed of two pairs of different non-

immunoglobulin proteins. See Table 7 for selected examples.

[0008] In general, the products in the type 1 category are useful in various applications where

a bivalent binding protein composed of two stably tethered Fab (or scFv) fragments derived

from the same monoclonal antibody is more desirable than the corresponding bivalent

F(ab')$_2$, which is known to dissociate into monovalent Fab' in vivo. For example, the efficacy

of an a_2 product composed of two stably tethered Fab fragments of 7E3 should be improved

over that of ReoPro^{TM} (Centocor, Inc.), which uses the Fab fragment of 7E3 to prevent

platelet aggregation.

[0009] In general, the products in the type 2 category are useful in various applications where

a bivalent agent may be more desirable than a monovalent agent either for improved efficacy

or pharmacokinetics or both. For example, an a_2 product composed of two copies of

erythropoietin may be preferred to Epogen® (Amgen), which contains only one

erythropoietin. Another example is an a_2 product composed of two copies of Aβ12-28P fused

to the CH2 and CH3 domains of human IgG1. Aβ12-28P is the peptide containing the N-

terminal 12 to 28 residues of β-amyloid (Aβ) with valine at position 18 replaced by proline.

Aβ12-28P is non-fibrillogenic and nontoxic and can block the binding of apolipoprotein E

(apoE) to Aβ with reduction of Aβ plaques in a transgenic mouse model (Sadowski et al.,

Am J Pathol. (2004), 165: 937-948). The fusion of CH2 and CH3 to Aβ12-28P would serve

two purposes: (1) to facilitate the resulting complex to cross the blood brain barrier through

the FcRn; (2) for effective reduction of Aβ plaque by microglia cells following binding of Aβ

to the anti-Aβ arms and binding of the CH2-CH3 domain to the Fc receptors on microglia

(Hartman et al., J. Neurosci. (2005), 25: 6213-6220).

[0010] In general, the products in the type 3 category are useful in various applications where

a tetravalent binding protein composed of four stably tethered Fab (or scFv) fragments

derived from the same monoclonal antibody is more desirable than a trivalent, bivalent or

monovalent binding protein based on the same monoclonal antibody. For example, the

efficacy of an a_4 product composed of four stably tethered Fab fragments of an anti-TNF-α

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antibody such as adalimumab may be more efficacious in treating arthritis than HUMIRA™ (Abbott Laboratories).

[0011] In general, the products in the type 4 category are useful in various applications where a tetravalent agent may be more desirable than a trivalent, bivalent or monovalent agent due to the enhanced avidity of binding to the target. For example, an a_4 product composed of four copies of factor IX may be preferred as a therapeutic agent for treating hemophilia to Benefix™ (Wyeth), which contains only one factor IX.

[0012] In general, the products in the type 5 category are useful in various applications where a bispecific tetravalent binding protein composed of two different a_2 subunits is desired. For example, an $a_2a'_2$ product composed of two Fab fragments of trastuzumab and two Fab fragments of pertuzumab may be more efficacious than either Herceptin® (Genentech) or Omnitarg™ (Genentech) for treating cancers that overexpress the HER2 receptor.

[0013] In general, the products in the type 6 category are useful in various applications where target-specific delivery or binding of a non-immunoglobulin protein is desired. For example, an $a_2a'_2$ product composed of two Fab fragments of an internalizing antibody against a tumor associated antigen (such as CD74) and two copies of a toxin (such as deglycosylated ricin A chain or ranpirnase) would be valuable for selective delivery of the toxin to destroy the target tumor cell. Another example is an $a_2a'_2$ product composed of two Fab fragments of an antibody against Aβ and two copies of transferin (Tf), which is expected to cross the blood brain barrier and neutralize Aβ for effective therapy of Alzheimer's disease.

[0014] In general, the products in the type 7 category are useful in various applications where the combination of two different non-immunoglobulin proteins are more desirable than each respective non-immunoglobulin protein alone. For example, an $a_2a'_2$ product composed of two copies of a soluble component of the receptor for IL-4R (sIL-4R) and two copies of a soluble component of the receptor for IL-13 (sIL-13R) would be a potential therapeutic agent for treating asthma or allergy. Another example is an $a_2a'_2$ product composed of two copies of Aβ12-28P and two copies of Tf. The addition of Tf to Aβ12-28P is expected to enable the resulting complex to cross the blood brain barrier for effective treatment of Alzheimer's disease.

[0015] The stably tethered structures of the present invention, including their conjugates, are suitable for use in a wide variety of therapeutic and diagnostic applications. For example, the a_2, a_4, or $a_2a'_2$ constructs based on the antibody binding domains can be used for therapy

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where such a construct is not conjugated to an additional functional agent, in the same manner as therapy using a naked antibody. Alternatively, these stably tethered structures can be derivatized with one or more functional agents to enable diagnostic or therapeutic applications. The additional agent may be covalently linked to the stably tethered structures using conventional conjugation chemistries.

[0016] Methods of use of stably tethered structures may include detection, diagnosis and/or treatment of a disease or other medical condition. Such conditions may include, but are not limited to, cancer, hyperplasia, diabetic retinopathy, macular degeneration, inflammatory bowel disease, Crohn's disease, ulcerative colitis, rheumatoid arthritis, sarcoidosis, asthma, edema, pulmonary hypertension, psoriasis, corneal graft rejection, neovascular glaucoma, Osler-Webber Syndrome, myocardial angiogenesis, plaque neovascularization, restenosis, neointima formation after vascular trauma, telangiectasia, hemophiliac joints, angiofibroma, fibrosis associated with chronic inflammation, lung fibrosis, deep venous thrombosis or wound granulation.

[0017] In particular embodiments, the disclosed methods and compositions may be of use to treat autoimmune disease, such as acute idiopathic thrombocytopenic purpura, chronic idiopathic thrombocytopenic purpura, dermatomyositis, Sydenham's chorea, myasthenia gravis, systemic lupus erythematosus, lupus nephritis, rheumatic fever, polyglandular syndromes, bullous pemphigoid, juvenile diabetes mellitus, Henoch-Schonlein purpura, post-streptococcalnephritis, erythema nodosum, Takayasu's arteritis, Addison's disease, rheumatoid arthritis, multiple sclerosis, sarcoidosis, ulcerative colitis, erythema multiforme, IgA nephropathy, polyarteritis nodosa, ankylosing spondylitis, Goodpasture's syndrome, thromboangitisubiterans, Sjogren's syndrome, primary biliary cirrhosis, Hashimoto's thyroiditis, thyrotoxicosis, scleroderma, chronic active hepatitis, polymyositis/dermatomyositis, polychondritis, pemphigus vulgaris, Wegener's granulomatosis, membranous nephropathy, amyotrophic lateral sclerosis, tabes dorsalis, giant cell arteritis/polymyalgia, pernicious anemia, rapidly progressive glomerulonephritis, psoriasis or fibrosing alveolitis.

[0018] In certain embodiments, the stably tethered structures may be of use for therapeutic treatment of cancer. It is anticipated that any type of tumor and any type of tumor antigen may be targeted. Exemplary types of tumors that may be targeted include acute lymphoblastic leukemia, acute myelogenous leukemia, biliary cancer, breast cancer, cervical cancer, chronic lymphocytic leukemia, chronic myelogenous leukemia, colorectal cancer,

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endometrial cancer, esophageal, gastric, head and neck cancer, Hodgkin's lymphoma, lung cancer, medullary thyroid cancer, non-Hodgkin's lymphoma, multiple myeloma, renal cancer, ovarian cancer, pancreatic cancer, glioma, melanoma, liver cancer, prostate cancer, and urinary bladder cancer.

[0019] Tumor-associated antigens that may be targeted include, but are not limited to, carbonic anhydrase IX, A3, antigen specific for A33 antibody, BrE3-antigen, CD1, CD1a, CD3, CD5, CD15, CD16, CD19, CD20, CD21, CD22, CD23, CD25, CD30, CD45, CD74, CD79a, CD80, HLA-DR, NCA 95, NCA90, HCG and its subunits, CEA (CEACAM-5), CEACAM-6, CSAp, EGFR, EGP-1, EGP-2, Ep-CAM, Ba 733, HER2/neu, hypoxia inducible factor (HIF), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, macrophage inhibition factor (MIF), MAGE, MUC1, MUC2, MUC3, MUC4, PAM-4-antigen, PSA, PSMA, RS5, S100, TAG-72, p53, tenascin, IL-6, IL-8, insulin growth factor-1 (IGF-1), Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGF, placenta growth factor (PlGF), 17-1A-antigen, an angiogenesis marker (e.g., ED-B fibronectin), an oncogene marker, an oncogene product, and other tumor-associated antigens. Recent reports on tumor associated antigens include Mizukami et al., (2005, *Nature Med.* 11:992-97); Hatfield et al., (2005, *Curr. Cancer Drug Targets* 5:229-48); Vallbohmer et al. (2005, *J. Clin. Oncol.* 23:3536-44); and Ren et al. (2005, *Ann. Surg.* 242:55-63), each incorporated herein by reference.

[0020] In other embodiments, the stably tethered structures may be of use to treat infection with pathogenic organisms, such as bacteria, viruses or fungi. Exemplary fungi that may be treated include *Microsporum, Trichophyton, Epidermophyton, Sporothrix schenckii, Cryptococcus neoformans, Coccidioides immitis, Histoplasma capsulatum, Blastomyces dermatitidis* or *Candida albican*. Exemplary viruses include human immunodeficiency virus (HIV), herpes virus, cytomegalovirus, rabies virus, influenza virus, human papilloma virus, hepatitis B virus, hepatitis C virus, Sendai virus, feline leukemia virus, Reo virus, polio virus, human serum parvo-like virus, simian virus 40, respiratory syncytial virus, mouse mammary tumor virus, Varicella-Zoster virus, Dengue virus, rubella virus, measles virus, adenovirus, human T-cell leukemia viruses, Epstein-Barr virus, murine leukemia virus, mumps virus, vesicular stomatitis virus, Sindbis virus, lymphocytic choriomeningitis virus or blue tongue virus. Exemplary bacteria include *Bacillus anthracis, Streptococcus agalactiae, Legionella pneumophilia, Streptococcus pyogenes, Escherichia coli, Neisseria gonorrhoeae, Neisseria meningitidis, Pneumococcus spp., Hemophilis influenzae B, Treponema pallidum, Lyme*

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disease spirochetes, *Pseudomonas aeruginosa, Mycobacterium leprae, Brucella abortus, Mycobacterium tuberculosis* or a *Mycoplasma.*

[0021] Although not limiting, in various embodiments, the precursors incorporated into the monomers, dimers and/or tetramers may comprise one or more proteins, such as a bacterial toxin, a plant toxin, ricin, abrin, a ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtherin toxin, Pseudomonas exotoxin, Pseudomonas endotoxin, Ranpirnase (Rap), Rap (N69Q), PE38, dgA, DT390, PLC, tPA, a cytokine, a growth factor, a soluble receptor component, surfactant protein D, IL-4, sIL-4R, sIL-13R, $VEGF_{121}$, TPO, EPO, a clot-dissolving agent, an enzyme, a fluorescent protein, sTNFα-R, an avimer, a scFv, a dsFv or a nanobody.

[0022] In other embodiments, an anti-angiogenic agent may form part or all of a precursor or may be attached to a stably tethered structure. Exemplary anti-angiogenic agents of use include angiostatin, baculostatin, canstatin, maspin, anti-VEGF antibodies or peptides, anti-placental growth factor antibodies or peptides, anti-Flk-1 antibodies, anti-Flt-1 antibodies or peptides, laminin peptides, fibronectin peptides, plasminogen activator inhibitors, tissue metalloproteinase inhibitors, interferons, interleukin 12, IP-10, Gro-ß, thrombospondin, 2-methoxyoestradiol, proliferin-related protein, carboxiamidotriazole, CM101, Marimastat, pentosan polysulphate, angiopoietin 2 , interferon-alpha, herbimycin A, PNU145156E, 16K prolactin fragment, Linomide, thalidomide, pentoxifylline, genistein, TNP-470, endostatin, paclitaxel, accutin, angiostatin, cidofovir, vincristine, bleomycin, AGM-1470, platelet factor 4 or minocycline.

[0023] In still other embodiments, one or more therapeutic agents, such as aplidin, azaribine, anastrozole, azacytidine, bleomycin, bortezomib, bryostatin-1, busulfan, calicheamycin, camptothecin, 10-hydroxycamptothecin, carmustine, celebrex, chlorambucil, cisplatin, irinotecan (CPT-11), SN-38, carboplatin, cladribine, cyclophosphamide, cytarabine, dacarbazine, docetaxel, dactinomycin, daunomycin glucuronide, daunorubicin, dexamethasone, diethylstilbestrol, doxorubicin, 2-pyrrolinodoxorubicine (2P-DOX), cyano-morpholino doxorubicin, doxorubicin glucuronide, epirubicin glucuronide, ethinyl estradiol, estramustine, etoposide, etoposide glucuronide, etoposide phosphate, floxuridine (FUdR), 3',5'-O-dioleoyl-FudR (FUdR-dO), fludarabine, flutamide, fluorouracil, fluoxymesterone, gemcitabine, hydroxyprogesterone caproate, hydroxyurea, idarubicin, ifosfamide, L-asparaginase, leucovorin, lomustine, mechlorethamine, medroprogesterone acetate, megestrol

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acetate, melphalan, mercaptopurine, 6-mercaptopurine, methotrexate, mitoxantrone, mithramycin, mitomycin, mitotane, phenyl butyrate, prednisone, procarbazine, paclitaxel, pentostatin, PSI-341, semustine streptozocin, tamoxifen, taxanes, taxol, testosterone propionate, thalidomide, thioguanine, thiotepa, teniposide, topotecan, uracil mustard, velcade, vinblastine, vinorelbine, vincristine, ricin, abrin, ribonuclease, onconase, rapLR1, DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, Pseudomonas endotoxin, an antisense oligonucleotide, an interference RNA, or a combination thereof, may be conjugated to or incorporated into a stably tethered structure.

[0024] In various embodiments, one or more effectors, such as a diagnostic agent, a therapeutic agent, a chemotherapeutic agent, a radioisotope, an imaging agent, an anti-angiogenic agent, a cytokine, a chemokine, a growth factor, a drug, a prodrug, an enzyme, a binding molecule, a ligand for a cell surface receptor, a chelator, an immunomodulator, an oligonucleotide, a hormone, a photodetectable label, a dye, a peptide, a toxin, a contrast agent, a paramagnetic label, an ultrasound label, a pro-apoptotic agent, a liposome, a nanoparticle or a combination thereof, may be attached to a stably tethered structure.

[0025] Various embodiments may concern stably tethered structures and methods of use of same that are of use to induce apoptosis of diseased cells. Further details may be found in U.S. Patent Application Publication No. 20050079184, the entire text of which is incorporated herein by reference. Such structures may comprise a first and/or second precursor with binding affinity for an antigen selected from the group consisting of CD2, CD3, CD8, CD10, CD21, CD23, CD24, CD25, CD30, CD33, CD37, CD38, CD40, CD48, CD52, CD55, CD59, CD70, CD74, CD80, CD86, CD138, CD147, HLA-DR, CEA, CSAp, CA-125, TAG-72, EFGR, HER2, HER3, HER4, IGF-1R, c-Met, PDGFR, MUC1, MUC2, MUC3, MUC4, TNFR1, TNFR2, NGFR, Fas (CD95), DR3, DR4, DR5, DR6, VEGF, PlGF, ED-B fibronectin, tenascin, PSMA, PSA, carbonic anhydrase IX, and IL-6. In more particular embodiments, a stably tethered structure of use to induce apoptosis may comprise monoclonal antibodies, Fab fragments, chimeric, humanized or human antibodies or fragments. In preferred embodiments, the stably tethered structure may comprise combinations of anti-CD74 X anti-CD20, anti-CD74 X anti-CD22, anti-CD22 X anti-CD20, anti-CD20 X anti-HLA-DR, anti-CD19 X anti-CD20, anti-CD20 X anti-CD80, anti-CD2 X anti-CD25, anti-CD8 X anti-CD25, and anti-CD2 X anti-CD147. In more preferred embodiments, the chimeric, humanized or human antibodies or antibody fragments may be

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derived from the variable domains of LL2 (anti-CD22), LL1 (anti-CD74) and A20 (anti-CD20).

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Figure 1 shows two exemplary DDD sequences. The underlined sequence in DDD1 (SEQ ID NO:1) corresponds to the first 44 amino-terminal residues found in the RIIα of human PKA. DDD2 (SEQ ID NO:2) differs from DDD1 in the two amino acid residues at the N-terminus.

[0027] Figure 2 shows a schematic diagram for pdHL2-based expression vectors for IgG (upper panel) and C-DDD1-Fab (lower panel).

[0028] Figure 3 shows a schematic diagram of C-DDD1-Fab-hMN-14 and the putative a₂ structure formed by DDD1 mediated dimerization.

[0029] Figure 4 shows a schematic diagram of N-DDD1-Fab-hMN-14 and the putative a₂ structure formed by DDD1 mediated dimerization.

[0030] Figure 5 shows the peptide sequence for AD1-C (SEQ ID NO:3).

[0031] Figure 6 shows SE-HPLC analysis of affinity-purified C-DDD1-Fab-hMN-14.

[0032] Figure 7 shows SDS-PAGE analysis of affinity-purified C-DDD1-Fab-hMN-14.

[0033] Figure 8 shows SE-HPLC analysis of affinity-purified N-DDD1-Fab-hMN-14.

[0034] Figure 9 shows C-DDD1-Fab-hMN-14 contains two active binding sites.

[0035] Figure 10 shows N-DDD1-Fab-hMN-14 contains two active binding sites

[0036] Figure 11 shows the binding affinity of C-DDD1-Fab-hMN-14 is at least equivalent to the bivalent hMN-14 IgG or F(ab')2 and about 5-fold higher than the monovalent Fab.

[0037] Figure 12 shows the binding affinity of N-DDD1-Fab-hMN-14 is equivalent to bivalent hMN-14 IgG and the binding affinity of C-DDD1-Fab-hMN-14 is higher than hMN-14 IgG.

[0038] Figure 13 shows C-DDD1-Fab-hMN-14 is stable in pooled human serum with no apparent change in molecular integrity over 96 h.

[0039] Figure 14 shows C-DDD1-Fab-hMN-14 is stable in pooled human serum with unchanged immunoreactivity over 28 h.

[0040] Figure 15 compares the tumor uptake of C-DDD1-Fab-hMN-14 with that of hBS14-1 in mice bearing human colorectal cancer xenografts.

[0041] Figure 16 compares the normal organ uptake of C-DDD1-Fab-hMN-14 with that of hBS14-1 in mice bearing human colorectal cancer xenografts

[0042] Figure 17 shows the SE-HPLC analysis of affinity-purified Rap-hPAM4-Fab-DDD1.

[0043] Figure 18 shows the binding affinity of Rap-hPAM4-Fab-DDD1 is equivalent to that of hPAM4 IgG.

[0044] Figure 19 shows the predominant presence of the a_4 form in N-DDD2-Fab-hMN-14 purified with CBind L (Protein L cellulose). The SE-HPLC trace also reveals the presence of the a_2 form, as well as free light chains in both monomeric and dimeric forms.

[0045] Figure 20 shows the dissociation of the a_4 form present in purified N-DDD2-Fab-hMN-14 to the a_2 form upon reduction with 5 mM TCEP, which also converts the dimeric light chain to monomeric light chain.

[0046] Figure 21 shows a schematic representation of the conversion of C-DDD2-Fab-hMN-14 in the a_4 form to the a_2 form upon reduction.

[0047] Figure 22 shows the SE-HPLC analysis of the tetravalent C-DDD2-Fab-hMN-14 after purification by Superdex-200 gel filtration chromatography. Two columns (Biosil SEC 250) were connected in tandem for increased resolution. The tetravalent C-DDD2-Fab-hMN-14 appears as a single peak (indicated as A_4) with a retention time of 19.58 min.

[0048] Figure 23 shows that the tetravalent C-DDD2-Fab-hMN-14 consists of four functional CEA-binding Fab fragments. The conditions of SE-HPLC were the same as described for Figure 22. (a) When WI2 Fab' was mixed with the tetravalent C-DDD2-Fab-hMN-14 at 1:1 molar ratio, four protein peaks representing the binding of the tetravalent C-DDD2-Fab-hMN-14 to one (indicated as 1, at 18.32 min), two (indicated as 2, at 17.45 min) or three (indicated as 3, at 16.92 min) WI2 Fab' fragments as well as the unbound form of C-DDD2-Fab-hMN-14 were observed. (b) When WI2 Fab' was mixed with the tetravalent C-DDD2-Fab-hMN-14 at 5: 1 molar ratio, only the complex consisting of the tetravalent C-DDD2-Fab-hMN-14 bound to four WI2 Fab fragment's was observed (indicated as 4) at 16.24 min. Excess WI2 Fab' (indicated as W) was detected at 24.17 min peak.

[0049] Figure 24 shows SE-HPLC analysis of the tetravalent C-DDD2-Fab-hA20 after purification by Superdex-200 gel filtration chromatography.

[0050] Figure 25 shows cell growth inhibition by the tetravalent C-DDD2-Fab-hA20 (abbreviated as hA20A4). Daudi (1-1) cells (upper panel) or Ramos cells (lower panel) were resuspended in 48-well plates in duplicate at a final density of 100,000 cells/mL in the complete medium containing 10 nM of hA20, hA20 F(ab')$_2$, or hA20A4, in the absence or presence of anti-IgM (0.1 ug/mL). The cells were incubated for 3 days and MTT assay was performed to determine the viable cell populations. Only hA20A4 caused significant growth

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inhibition (40 to 50 %) in the absence of anti-IgM. Figure 26 shows the presence of the bispecific tetravalent hMN-3xhA20 by ELISA.

[0052] Figure 27 shows the presence of bispecific tetravalent hMN-3xhMN-14 by flow cytometry. BXPC3 cells, which express high levels of CEACAM6 but only background levels of CEACAM5,were incubated for 1 h at RT with each of the samples (10ug/mL) in the presence of Alexa-532-WI2, a rat anti-ideotypic mAb for hMN-14 labeled with a fluorescent tag, and analyzed by flow cytometry using Guava PCA. Only the histogram of the sample containing bispecific hMN-3xhMN-14 showed positively stained BXPC3 cells.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0053] All documents, or portions of documents, cited in this application, including but not limited to patents, patent applications, articles, books, and treatises, are hereby expressly incorporated by reference in their entirety.

Definitions

[0054] As used herein, "a" or "an" may mean one or more than one of an item.

[0055] As used herein, the terms "and" and "or" may be used to mean either the conjunctive or disjunctive. That is, both terms should be understood as equivalent to "and/or" unless otherwise stated.

[0056] An antibody, as described herein, refers to a full-length (i.e., naturally occurring or formed by normal immunoglobulin gene fragment recombinatorial processes) immunoglobulin molecule (e.g., an IgG antibody) or an immunologically active (i.e., specifically binding) portion or analog of an immunoglobulin molecule, like an antibody fragment.

[0057] An antibody fragment is a portion of an antibody such as F(ab)₂, F(ab')₂, Fab, Fv, sFv and the like. Regardless of structure, an antibody fragment binds with the same antigen that is recognized by the intact antibody. The term "antibody fragment" also includes any synthetic or genetically engineered protein that acts like an antibody by binding to a specific antigen to form a complex. For example, antibody fragments include isolated fragments consisting of the variable regions, such as the "Fv" fragments consisting of the variable regions of the heavy and light chains, recombinant single chain polypeptide molecules in which light and heavy variable regions are connected by a peptide linker ("scFv proteins"), and minimal recognition units (CDR) consisting of the amino acid residues that mimic the hypervariable region.

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[0058] An effector is an atom, molecule, or compound that brings about a chosen result. An effector may include a therapeutic agent and/or a diagnostic agent.

[0059] A therapeutic agent is an atom, molecule, or compound that is useful in the treatment of a disease. Examples of therapeutic agents include antibodies, antibody fragments, drugs, toxins, enzymes, nucleases, hormones, immunomodulators, antisense oligonucleotides, small interfering RNA (siRNA), chelators, boron compounds, photoactive agents, dyes, and radioisotopes. Other exemplary therapeutic agents and methods of use are disclosed in U.S. Patent Publication Nos. 20050002945, 20040018557, 20030148409 and 20050014207, each incorporated herein by reference.

[0060] A diagnostic agent is an atom, molecule, or compound that is useful in diagnosing a disease. Useful diagnostic agents include, but are not limited to, radioisotopes, dyes (such as with the biotin-streptavidin complex), contrast agents, fluorescent compounds or molecules, and enhancing agents (e.g., paramagnetic ions) for magnetic resonance imaging (MRI).

[0061] An immunoconjugate is a conjugate of a binding molecule (e.g., an antibody component) with an atom, molecule, or a higher-ordered structure (e.g., with a carrier, a therapeutic agent, or a diagnostic agent).

[0062] A naked antibody is an antibody that is not conjugated to any other agent.

[0063] A carrier is an atom, molecule, or higher-ordered structure that is capable of associating with a therapeutic or diagnostic agent to facilitate delivery of such agent to a targeted cell. Carriers may include lipids (e.g., amphiphilic lipids that are capable of forming higher-ordered structures), polysaccharides (such as dextran), or other higher-ordered structures, such as micelles, liposomes, or nanoparticles.

[0064] As used herein, the term antibody fusion protein is a recombinantly produced antigen-binding molecule in which two or more of the same or different scFv or antibody fragments with the same or different specificities are linked. Valency of the fusion protein indicates how many binding arms or sites the fusion protein has to a single antigen or epitope; i.e., monovalent, bivalent, trivalent or multivalent. The multivalency of the antibody fusion protein means that it can take advantage of multiple interactions in binding to an antigen, thus increasing the avidity of binding to the antigen. Specificity indicates how many antigens or epitopes an antibody fusion protein is able to bind; i.e., monospecific, bispecific, trispecific, multispecific. Using these definitions, a natural antibody, e.g., an IgG, is bivalent because it has two binding arms but is monospecific because it binds to one epitope. Monospecific,

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multivalent fusion proteins have more than one binding site for an epitope but only binds to one such epitope, for example a diabody with two binding site reactive with the same antigen. The fusion protein may comprise a single antibody component, a multivalent or multispecific combination of different antibody components, or multiple copies of the same antibody component. The fusion protein may additionally comprise an antibody or an antibody fragment and a therapeutic agent. Examples of therapeutic agents suitable for such fusion proteins include immunomodulators ("antibody-immunomodulator fusion protein") and toxins ("antibody-toxin fusion protein"). One preferred toxin comprises a ribonuclease (RNase), preferably a recombinant RNase.

[0065] An antibody or immunoconjugate preparation, or a composition described herein, is said to be administered in a "therapeutically effective amount" if the amount administered is physiologically significant. An agent is physiologically significant if its presence results in a detectable change in the physiology of a recipient mammal. In particular, an antibody preparation is physiologically significant if its presence invokes an antitumor response or mitigates the signs and symptoms of an autoimmune disease state. A physiologically significant effect could also be the evocation of a humoral and/or cellular immune response in the recipient mammal leading to growth inhibition or death of target cells.

Conjugates of the Stably Tethered Structures

[0066] Additional moieties can be conjugated to the stably tethered structures described above. For example, drugs, toxins, radioactive compounds, enzymes, hormones, cytotoxic proteins, chelates, cytokines, and other functional agents may be conjugated to the stably tethered structures. Conjugation can be via, for example, covalent attachments to amino acid residues containing amine, carboxyl, thiol or hydroxyl groups in the side-chains . Various conventional linkers may be used for this purpose, for example, diisocyanates, diisothiocyanates, bis(hydroxysuccinimide) esters, carbodiimides, maleimide-hydroxysuccinimide esters, glutaraldehyde and the like. Conjugation of agents to the stably tethered structures preferably does not significantly affect the activity of each subunit contained in the unmodified structures. Conjugation can be carried out separately to the a_4 and a'_4 constructs and the resulting conjugates are used for preparing the $a_2a'_2$ constructs In addition, cytotoxic agents may be first coupled to a polymeric carrier, which is then conjugated to a stably tethered structure. For this method, see Ryser *et al., Proc. Natl. Acad. Sci. USA*, 75:3867-3870, 1978; U.S. 4,699,784 and U.S. 4,046,722, which are incorporated herein by reference.

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[0067] The conjugates described herein can be prepared by various methods known in the art. For example, a stably tethered structure can be radiolabeled with ^{131}I and conjugated to a lipid, such that the resulting conjugate can form a liposome. The liposome may incorporate one or more therapeutic (e.g., a drug such as FUdR-dO) or diagnostic agents. Alternatively, in addition to the carrier, a stably tethered structure may be conjugated to ^{131}I (e.g., at a tyrosine residue) and a drug (e.g., at the epsilon amino group of a lysine residue), and the carrier may incorporate an additional therapeutic or diagnostic agent. Therapeutic and diagnostic agents may be covalently associated with one or more than one subunit of the stably tethered structures.

[0068] The formation of liposomes and micelles is known in the art. See, e.g., Wrobel and Collins, Biochimica et Biophysica Acta (1995), 1235: 296-304; Lundberg et al., J. Pharm. Pharmacol. (1999), 51:1099-1105; Lundberg et al., Int. J. Pharm. (2000), 205:101-108; Lundberg, J. Pharm. Sci. (1994), 83:72-75; Xu et al., Molec. Cancer Ther. (2002), 1:337-346; Torchilin et al., Proc. Nat'l. Acad. Sci., U.S.A. (2003), 100:6039-6044; U.S. 5,565,215; U.S. 6,379,698; and U.S. 2003/0082154.

[0069] Nanoparticles or nanocapsules formed from polymers, silica, or metals, which are useful for drug delivery or imaging, have been described as well. See, e.g., West et al., Applications of Nanotechnology to Biotechnology (2000), 11:215-217; U.S. 5,620,708; U.S. 5,702,727; and U.S. 6,530,944. The conjugation of antibodies or binding molecules to liposomes to form a targeted carrier for therapeutic or diagnostic agents has been described. See, e.g., Bendas, Biodrugs (2001), 15:215-224; Xu et al., Mol. Cancer Ther (2002), 1:337-346; Torchilin et al., Proc. Nat'l. Acad. Sci. U.S.A (2003), 100:6039-6044; Bally, et al., J. Liposome Res.(1998), 8:299-335; Lundberg, Int. J. Pharm. (1994), 109:73-81; Lundberg, J. Pharm. Pharmacol. (1997), 49:16-21; Lundberg, Anti-cancer Drug Design (1998), 13: 453-461. See also U.S. 6,306,393; U.S. Serial No. 10/350,096; U.S. Serial No. 09/590,284, and U.S. Serial No. 60/138,284, filed June 9, 1999. All these references are incorporated herein by reference.

[0070] A wide variety of diagnostic and therapeutic agents can be advantageously used to form the conjugates of the stably tethered structures, or may be linked to haptens that bind to a recognition site on the stably tethered structures. Diagnostic agents may include radioisotopes, enhancing agents for use in MRI or contrast agents for ultrasound imaging, and fluorescent compounds. Many appropriate imaging agents are known in the art, as are methods for their attachment to proteins or peptides (see, e.g., U.S. patents 5,021,236 and

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4,472,509, both incorporated herein by reference). Certain attachment methods involve the use of a metal chelate complex employing, for example, an organic chelating agent such a DTPA attached to the protein or peptide (U.S. Patent 4,472,509).

[0071] In order to load a stably tethered structure with radioactive metals or paramagnetic ions, it may be necessary to first react it with a carrier to which multiple copies of a chelating group for binding the radioactive metals or paramagnetic ions have been attached. Such a carrier can be a polylysine, polysaccharide, or a derivatized or derivatizable polymeric substance having pendant groups to which can be bound chelating groups such as, e.g., ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), porphyrins, polyamines, crown ethers, bis-thiosemicarbazones, polyoximes, and the like known to be useful for this purpose. Carriers containing chelates are coupled to the stably tethered structure using standard chemistries in a way to minimize aggregation and loss of immunoreactivity.

[0072] Other, more unusual, methods and reagents that may be applied for preparing such conjugates are disclosed in U.S. 4,824,659, which is incorporated herein in its entirety by reference. Particularly useful metal-chelate combinations include 2-benzyl-DTPA and its monomethyl and cyclohexyl analogs, used with diagnostic isotopes in the general energy range of 60 to 4,000 keV. Some useful diagnostic nuclides may include ^{18}F, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{89}Zr, ^{94}Tc, ^{94m}Tc, ^{99m}Tc, or ^{111}In. The same chelates complexed with non-radioactive metals, such as manganese, iron and gadolinium, are useful for MRI, when used along with the stably tethered structures and carriers described herein. Macrocyclic chelates such as NOTA, DOTA, and TETA are of use with a variety of metals and radiometals, most particularly with radionuclides of gallium, yttrium and copper, respectively. Such metal-chelate complexes can be made very stable by tailoring the ring size to the metal of interest. Other ring-type chelates, such as macrocyclic polyethers for complexing ^{223}Ra, may be used.

[0073] Therapeutic agents include, for example, chemotherapeutic drugs such as vinca alkaloids, anthracyclines, epidophyllotoxins, taxanes, antimetabolites, alkylating agents, antibiotics, Cox-2 inhibitors, antimitotics, antiangiogenic and proapoptotic agents, particularly doxorubicin, methotrexate, taxol, CPT-11, camptothecans, and others from these and other classes of anticancer agents, and the like. Other cancer chemotherapeutic drugs include nitrogen mustards, alkyl sulfonates, nitrosoureas, triazenes, folic acid analogs, pyrimidine analogs, purine analogs, platinum coordination complexes, hormones, and the

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like. Suitable chemotherapeutic agents are described in REMINGTON'S

PHARMACEUTICAL SCIENCES, 19th Ed. (Mack Publishing Co. 1995), and in

GOODMAN AND GILMAN'S THE PHARMACOLOGICAL BASIS OF

THERAPEUTICS, 7th Ed. (MacMillan Publishing Co. 1985), as well as revised editions of

these publications. Other suitable chemotherapeutic agents, such as experimental drugs, are

known to those of skill in the art, and may be conjugated to the stably tethered structures

described herein using methods that are known in the art.

[0074] Another class of therapeutic agents consists of radionuclides that emit α-particles

(such as ^{212}Pb, ^{212}Bi, ^{213}Bi, ^{211}At, ^{223}Ra, ^{225}Ac), β-particles (such as ^{32}P, ^{33}P, ^{47}Sc, ^{67}Cu, ^{67}Ga,

^{89}Sr, ^{90}Y, ^{111}Ag, ^{125}I, ^{131}I, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{166}Ho, ^{166}Dy, ^{177}Lu, ^{186}Re, ^{188}Re, ^{189}Re), or

Auger electrons (such as ^{111}In, ^{125}I, ^{67}Ga, ^{191}Os, ^{193m}Pt, ^{195m}Pt, ^{195m}Hg). The stably tethered

structures may be labeled with one or more of the above radionuclides using methods as

described for the diagnostic agents.

[0075] A suitable peptide containing a detectable label (e.g., a fluorescent molecule), or a

cytotoxic agent, (e.g., a radioiodine), can be covalently, non-covalently, or otherwise

associated with the stably tethered structures. For example, a therapeutically useful conjugate

can be obtained by incorporating a photoactive agent or dye onto the stably tethered

structures. Fluorescent compositions, such as fluorochrome, and other chromogens, or dyes,

such as porphyrins sensitive to visible light, have been used to detect and to treat lesions by

directing the suitable light to the lesion. In therapy, this has been termed photoradiation,

phototherapy, or photodynamic therapy. See Jori et al. (eds.), PHOTODYNAMIC

THERAPY OF TUMORS AND OTHER DISEASES (Libreria Progetto 1985); van den

Bergh, Chem. Britain (1986), 22:430. Moreover, monoclonal antibodies have been coupled

with photoactivated dyes for achieving phototherapy. See Mew et al., J. Immunol.

(1983),130:1473; idem., Cancer Res. (1985), 45:4380; Oseroff et al., Proc. Natl. Acad. Sci.

USA (1986), 83:8744; idem., Photochem. Photobiol. (1987), 46:83; Hasan et al., Prog. Clin.

Biol. Res. (1989), 288:471; Tatsuta et al., Lasers Surg. Med. (1989), 9:422; Pelegrin et al.,

Cancer (1991), 67:2529. Endoscopic applications are also contemplated. Endoscopic

methods of detection and therapy are described in U.S. 4,932,412; U.S. 5,525,338; U.S.

5,716,595; U.S. 5,736,119; U.S. 5,922,302; U.S. 6,096,289; and U.S. 6,387,350, which are

incorporated herein by reference in their entirety.

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[0076] In certain embodiments, the novel constructs and methods disclosed herein are useful for targeted delivery of RNAi for therapeutic intervention. The delivery vehicle can be either an a2 (dimer) or an a4 (tetramer) structure with an internalizing antibody binding domain fused to human protamine (peptide of ~ 50 amino acid residues) as its precursor. An example of an a2 construct would be VH-CH1-hP1-DDD1//VL-CL or VH-CH1-hP2-DDD1//VL-CL, where hP1 and hP2 are human protamine 1 and human protamine 2, respectively; both capable of forming stable DNA complexes for in vivo applications (Nat Biotechnol. 23: 709-717, 2005; Gene Therapy. 13: 194-195, 2006). An example of an a4 construct would be VH-CH1-hP1-DDD2//VL-CL or VH-CH1-hP2-DDD2//VL-CL, which would provide four active Fab fragments, each carrying a human protamine for binding to RNAi. The multivalent complex will facilitate the binding to and receptor-mediated internalization into target cells, where the noncovalently bound RNAi is dissociated in the endosomes and released into cytoplasm. As no redox chemistry is involved, the existence of 3 intramolecular disulfide bonds in hP1 or hP2 does not present a problem. In addition to delivery of RNAi, these constructs may also be of use for targeted delivery of therapeutic genes or DNA vaccines. Another area of use is to apply the A4/A2 technology for producing intrabodies, which is the protein analog of RNAi in terms of function.

Peptide Administration

[0077] Various embodiments of the claimed methods and/or compositions may concern one or more peptide based stably tethered structures to be administered to a subject. Administration may occur by any route known in the art, including but not limited to oral, nasal, buccal, inhalational, rectal, vaginal, topical, orthotopic, intradermal, subcutaneous, intramuscular, intraperitoneal, intraarterial, intrathecal or intravenous injection.

[0078] Unmodified peptides administered orally to a subject can be degraded in the digestive tract and depending on sequence and structure may exhibit poor absorption across the intestinal lining. However, methods for chemically modifying peptides to render them less susceptible to degradation by endogenous proteases or more absorbable through the alimentary tract are well known (see, for example, Blondelle et al., 1995, Biophys. J. 69:604-11; Ecker and Crooke, 1995, Biotechnology 13:351-69; Goodman and Ro, 1995, BURGER'S MEDICINAL CHEMISTRY AND DRUG DISCOVERY, VOL. I, ed. Wollf, John Wiley & Sons; Goodman and Shao, 1996, Pure & Appl. Chem. 68:1303-08). Methods for preparing libraries of peptide analogs, such as peptides containing D-amino acids; peptidomimetics consisting of organic molecules that mimic the structure of a peptide; or peptoids such as

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vinylogous peptoids, have also been described and may be used to construct peptide based stably tethered structures suitable for oral administration to a subject.

[0079] In certain embodiments, the standard peptide bond linkage may be replaced by one or more alternative linking groups, such as CH_2-NH, CH_2-S, CH_2-CH_2, CH=CH, CO-CH_2, CHOH-CH_2 and the like. Methods for preparing peptide mimetics are well known (for example, Hruby, 1982, *Life Sci* 31:189-99; Holladay et al., 1983, *Tetrahedron Lett.* 24:4401-04; Jennings-White et al., 1982, *Tetrahedron Lett.* 23:2533; Almquiest et al., 1980, *J. Med. Chem.* 23:1392-98; Hudson et al., 1979, *Int. J. Pept. Res.* 14:177-185; Spatola et al., 1986, *Life Sci* 38:1243-49; U.S. Patent Nos. 5,169,862; 5,539,085; 5,576,423, 5,051,448, 5,559,103, each incorporated herein by reference.) Peptide mimetics may exhibit enhanced stability and/or absorption *in vivo* compared to their peptide analogs.

[0080] Alternatively, peptides may be administered by oral delivery using N-terminal and/or C-terminal capping to prevent exopeptidase activity. For example, the C-terminus may be capped using amide peptides and the N-terminus may be capped by acetylation of the peptide. Peptides may also be cyclized to block exopeptidases, for example by formation of cyclic amides, disulfides, ethers, sulfides and the like.

[0081] Peptide stabilization may also occur by substitution of D-amino acids for naturally occurring L-amino acids, particularly at locations where endopeptidases are known to act. Endopeptidase binding and cleavage sequences are known in the art and methods for making and using peptides incorporating D-amino acids have been described (*e.g.*, U.S. Patent Application Publication No. 20050025709, McBride et al., filed June 14, 2004, incorporated herein by reference). In certain embodiments, peptides and/or proteins may be orally administered by co-formulation with proteinase- and/or peptidase-inhibitors.

[0082] Other methods for oral delivery of therapeutic peptides are disclosed in Mehta ("Oral delivery and recombinant production of peptide hormones," June 2004, *BioPharm International*). The peptides are administered in an enteric-coated solid dosage form with excipients that modulate intestinal proteolytic activity and enhance peptide transport across the intestinal wall. Relative bioavailability of intact peptides using this technique ranged from 1% to 10% of the administered dosage. Insulin has been successfully administered in dogs using enteric-coated microcapsules with sodium cholate and a protease inhibitor (Ziv et al., 1994, *J. Bone Miner. Res.* 18 (Suppl. 2):792-94. Oral administration of peptides has been performed using acylcarnitine as a permeation enhancer and an enteric coating (Eudragit

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L30D-55, Rohm Pharma Polymers, *see* Mehta, 2004). Excipients of use for orally administered peptides may generally include one or more inhibitors of intestinal proteases/peptidases along with detergents or other agents to improve solubility or absorption of the peptide, which may be packaged within an enteric-coated capsule or tablet (Mehta, 2004). Organic acids may be included in the capsule to acidify the intestine and inhibit intestinal protease activity once the capsule dissolves in the intestine (Mehta, 2004). Another alternative for oral delivery of peptides would include conjugation to polyethylene glycol (PEG)-based amphiphilic oligomers, increasing absorption and resistance to enzymatic degradation (Soltero and Ekwuribe, 2001, *Pharm. Technol.* 6:110).

[0083] In still other embodiments, peptides may be modified for oral or inhalational administration by conjugation to certain proteins, such as the Fc region of IgG1 (see Examples 3-7). Methods for preparation and use of peptide-Fc conjugates are disclosed, for example, in Low et al. (2005, *Hum. Reprod.* 20:1805-13) and Dumont et al. (2005, *J. Aerosol. Med.* 18:294-303), each incorporated herein by reference. Low et al. (2005) disclose the conjugation of the alpha and beta subunits of FSH to the Fc region of IgG1 in single chain or heterodimer form, using recombinant expression in CHO cells. The Fc conjugated peptides were absorbed through epithelial cells in the lung or intestine by the neonatal Fc receptor mediated transport system. The Fc conjugated peptides exhibited improved stability and absorption *in vivo* compared to the native peptides. It was also observed that the heterodimer conjugate was more active than the single chain form.

Proteins and Peptides

[0084] A variety of polypeptides or proteins may be used within the scope of the claimed methods and compositions. In certain embodiments, the proteins may comprise antibodies or fragments of antibodies containing an antigen-binding site. As used herein, a protein, polypeptide or peptide generally refers, but is not limited to, a protein of greater than about 200 amino acids, up to a full length sequence translated from a gene; a polypeptide of greater than about 100 amino acids; and/or a peptide of from about 3 to about 100 amino acids. For convenience, the terms "protein," "polypeptide" and "peptide" are used interchangeably herein. Accordingly, the term "protein or peptide" encompasses amino acid sequences comprising at least one of the 20 common amino acids found in naturally occurring proteins, or at least one modified or unusual amino acid.

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[0085] As used herein, an "amino acid residue" refers to any naturally occurring amino acid, any amino acid derivative or any amino acid mimic known in the art. In certain embodiments, the residues of the protein or peptide are sequential, without any non-amino acid interrupting the sequence of amino acid residues. In other embodiments, the sequence may comprise one or more non-amino acid moieties. In particular embodiments, the sequence of residues of the protein or peptide may be interrupted by one or more non-amino acid moieties.

[0086] Accordingly, the term "protein or peptide" encompasses amino acid sequences comprising at least one of the 20 common amino acids found in naturally occurring proteins, or at least one modified or unusual amino acid, including but not limited to those shown below.

Modified and Unusual Amino Acids			
Abbr.	Amino Acid	Abbr.	Amino Acid
Aad	2-Aminoadipic acid	EtAsn	N-Ethylasparagine
Baad	3- Aminoadipic acid	Hyl	Hydroxylysine
Bala	β-alanine, β-Amino-propionic acid	AHyl	allo-Hydroxylysine
Abu	2-Aminobutyric acid	3Hyp	3-Hydroxyproline
4Abu	4- Aminobutyric acid, piperidinic acid	4Hyp	4-Hydroxyproline
Acp	6-Aminocaproic acid	Ide	Isodesmosine
Ahe	2-Aminoheptanoic acid	AIle	allo-Isoleucine
Aib	2-Aminoisobutyric acid	MeGly	N-Methylglycine, sarcosine
Baib	3-Aminoisobutyric acid	MeIle	N-Methylisoleucine
Apm	2-Aminopimelic acid	MeLys	6-N-Methyllysine
Dbu	2,4-Diaminobutyric acid	MeVal	N-Methylvaline
Des	Desmosine	Nva	Norvaline
Dpm	2,2'-Diaminopimelic acid	Nle	Norleucine
Dpr	2,3-Diaminopropionic acid	Orn	Ornithine
EtGly	N-Ethylglycine		

[0087] Proteins or peptides may be made by any technique known to those of skill in the art, including the expression of proteins, polypeptides or peptides through standard molecular

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biological techniques, the isolation of proteins or peptides from natural sources, or the chemical synthesis of proteins or peptides. The nucleotide and protein, polypeptide and peptide sequences corresponding to various genes have been previously disclosed and may be found at computerized databases known to those of ordinary skill in the art. One such database is the National Center for Biotechnology Information's Genbank and GenPept databases (www.ncbi.nlm.nih.gov/). The coding regions for known genes may be amplified and/or expressed using the techniques disclosed herein or as would be know to those of ordinary skill in the art. Alternatively, various commercial preparations of proteins, polypeptides, and peptides are known to those of skill in the art.

Peptide mimetics

[0088] Another embodiment for the preparation of polypeptides is the use of peptide mimetics. Mimetics are peptide-containing molecules that mimic elements of protein secondary structure. See, for example, Johnson *et al.,* "Peptide Turn Mimetics" in *BIOTECHNOLOGY AND PHARMACY*, Pezzuto *et al.,* Eds., Chapman and Hall, New York (1993), incorporated herein by reference. The rationale behind the use of peptide mimetics is that the peptide backbone of proteins exists chiefly to orient amino acid side chains so as to facilitate molecular interactions, such as those of antibody and antigen. A peptide mimetic is expected to permit molecular interactions similar to the natural molecule.

Fusion proteins

[0089] Various embodiments may concern fusion proteins. These molecules generally have all or a substantial portion of a peptide, linked at the N- or C-terminus, to all or a portion of a second polypeptide or protein. Methods of generating fusion proteins are well known to those of skill in the art. Such proteins may be produced, for example, by chemical attachment using bifunctional cross-linking reagents, by *de novo* synthesis of the complete fusion protein, or by attachment of a DNA sequence encoding a first protein or peptide to a DNA sequence encoding a second peptide or protein, followed by expression of the intact fusion protein.

Synthetic Peptides

[0090] Proteins or peptides may be synthesized, in whole or in part, in solution or on a solid support in accordance with conventional techniques. Various automatic synthesizers are commercially available and can be used in accordance with known protocols. See, for example, Stewart and Young, (1984, *Solid Phase Peptide Synthesis*, 2d. ed., Pierce Chemical

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Co.); Tam *et al.*, (1983, *J. Am. Chem. Soc.*, 105:6442); Merrifield, (1986, *Science*, 232: 341-347); and Barany and Merrifield (1979, *The Peptides*, Gross and Meienhofer, eds., Academic Press, New York, pp. 1-284). Short peptide sequences, usually from about 6 up to about 35 to 50 amino acids, can be readily synthesized by such methods. Alternatively, recombinant DNA technology may be employed wherein a nucleotide sequence which encodes a peptide of interest is inserted into an expression vector, transformed or transfected into an appropriate host cell, and cultivated under conditions suitable for expression.

Antibodies

[0091] Various embodiments may concern antibodies for a target. The term "antibody" is used herein to refer to any antibody-like molecule that has an antigen binding region, and includes antibody fragments such as Fab', Fab, F(ab')$_2$, single domain antibodies (DABs), Fv, scFv (single chain Fv), and the like. Techniques for preparing and using various antibody-based constructs and fragments are well known in the art. Means for preparing and characterizing antibodies are also well known in the art (See, *e.g.,* Harlowe and Lane, 1988, *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory). Antibodies of use may also be commercially obtained from a wide variety of known sources. For example, a variety of antibody secreting hybridoma lines are available from the American Type Culture Collection (ATCC, Manassas, VA).

Production of Antibody Fragments

[0092] Some embodiments of the claimed methods and/or compositions may concern antibody fragments. Such antibody fragments may be obtained by pepsin or papain digestion of whole antibodies by conventional methods. For example, antibody fragments may be produced by enzymatic cleavage of antibodies with pepsin to provide F(ab')$_2$ fragments . This fragment may be further cleaved using a thiol reducing agent and, optionally, followed by a blocking group for the sulfhydryl groups resulting from cleavage of disulfide linkages, to produce Fab' monovalent fragments. Alternatively, an enzymatic cleavage using papain n produces two monovalent Fab fragments and an Fc fragment. Exemplary methods for producing antibody fragments are disclosed in U.S. Pat. No. 4,036,945; U.S. Pat. No. 4,331,647; Nisonoff et al., 1960, Arch. Biochem. Biophys., 89:230; Porter, 1959, Biochem. J., 73:119; Edelman et al., 1967, METHODS IN ENZYMOLOGY, page 422 (Academic Press), and Coligan et al. (eds.), 1991, CURRENT PROTOCOLS IN IMMUNOLOGY, (John Wiley & Sons).

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[0093] Other methods of cleaving antibodies, such as separation of heavy chains to form monovalent light-heavy chain fragments, further cleavage of fragments or other enzymatic, chemical or genetic techniques also may be used, so long as the fragments bind to the antigen that is recognized by the intact antibody. For example, Fv fragments comprise an association of V_H and V_L chains. This association can be noncovalent, as described in Inbar et al., 1972, Proc. Nat'l. Acad. Sci. USA, 69:2659. Alternatively, the variable chains may be linked by an intermolecular disulfide bond or cross-linked by chemicals such as glutaraldehyde. See Sandhu, 1992, Crit. Rev. Biotech., 12:437.

[0094] Preferably, the Fv fragments comprise V_H and V_L chains connected by a peptide linker. These single-chain antigen binding proteins (sFv) are prepared by constructing a structural gene comprising DNA sequences encoding the V_H and V_L domains, connected by an oligonucleotides linker sequence. The structural gene is inserted into an expression vector that is subsequently introduced into a host cell, such as E. coli. The recombinant host cells synthesize a single polypeptide chain with a linker peptide bridging the two V domains. Methods for producing sFv's are well-known in the art. See Whitlow et al., 1991, Methods: A Companion to Methods in Enzymology 2:97; Bird et al., 1988, Science, 242:423; U.S. Pat. No. 4,946,778; Pack et al., 1993, Bio/Technology, 11:1271, and Sandhu, 1992, Crit. Rev. Biotech., 12:437.

[0095] Another form of an antibody fragment is a peptide coding for a single complementarity-determining region (CDR). CDR peptides ("minimal recognition units") can be obtained by constructing genes encoding the CDR of an antibody of interest. Such genes are prepared, for example, by using the polymerase chain reaction to synthesize the variable region from RNA of antibody-producing cells. See Larrick et al., 1991, Methods: A Companion to Methods in Enzymology 2:106; Ritter et al. (eds.), 1995, MONOCLONAL ANTIBODIES: PRODUCTION, ENGINEERING AND CLINICAL APPLICATION, pages 166-179 (Cambridge University Press); Birch et al., (eds.), 1995, MONOCLONAL ANTIBODIES: PRINCIPLES AND APPLICATIONS, pages 137-185 (Wiley-Liss, Inc.).

Chimeric and Humanized Antibodies

[0096] A chimeric antibody is a recombinant protein in which the variable regions of a human antibody have been replaced by the variable regions of, for example, a mouse antibody, including the complementarity-determining regions (CDRs) of the mouse antibody. Chimeric antibodies exhibit decreased immunogenicity and increased stability when

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administered to a subject. Methods for constructing chimeric antibodies are well known in the art (*e.g.*, Leung et al., 1994, Hybridoma 13:469).

[0097] A chimeric monoclonal antibody may be humanized by transferring the mouse CDRs from the heavy and light variable chains of the mouse immunoglobulin into the corresponding variable domains of a human antibody. The mouse framework regions (FR) in the chimeric monoclonal antibody are also replaced with human FR sequences. To preserve the stability and antigen specificity of the humanized monoclonal, one or more human FR residues may be replaced by the mouse counterpart residues. Humanized monoclonal antibodies may be used for therapeutic treatment of subjects. The affinity of humanized antibodies for a target may also be increased by selected modification of the CDR sequences (WO0029584A1). Techniques for production of humanized monoclonal antibodies are well known in the art. (See, *e.g.*, Jones et al., 1986, Nature, 321:522; Riechmann et al., Nature, 1988, 332:323; Verhoeyen et al., 1988, Science, 239:1534; Carter et al., 1992, Proc. Nat'l Acad. Sci. USA, 89:4285; Sandhu, Crit. Rev. Biotech., 1992, 12:437; Tempest et al., 1991, Biotechnology 9:266; Singer et al., J. Immunol., 1993, 150:2844.)

[0098] Other embodiments may concern non-human primate antibodies. General techniques for raising therapeutically useful antibodies in baboons may be found, for example, in Goldenberg et al., WO 91/11465 (1991), and in Losman et al., Int. J. Cancer 46: 310 (1990).

Human Antibodies

[0099] Methods for producing fully human antibodies using either combinatorial approaches or transgenic animals transformed with human immunoglobulin loci are known in the art (*e.g.*, Mancini et al., 2004, *New Microbiol.* 27:315-28; Conrad and Scheller, 2005, *Comb. Chem. High Throughput Screen.* 8:117-26; Brekke and Loset, 2003, *Curr. Opin. Phamacol.* 3:544-50; each incorporated herein by reference). Such fully human antibodies are expected to exhibit even fewer side effects than chimeric or humanized antibodies and to function *in vivo* as essentially endogenous human antibodies. In certain embodiments, the claimed methods and procedures may utilize human antibodies produced by such techniques.

[0100] In one alternative, the phage display technique may be used to generate human antibodies (*e.g.*, Dantas-Barbosa et al., 2005, *Genet. Mol. Res.* 4:126-40, incorporated herein by reference). Human antibodies may be generated from normal humans or from humans that exhibit a particular disease state, such as cancer (Dantas-Barbosa et al., 2005). The

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advantage to constructing human antibodies from a diseased individual is that the circulating antibody repertoire may be biased towards antibodies against disease-associated antigens.

[0101] In one non-limiting example of this methodology, Dantas-Barbosa et al. (2005) constructed a phage display library of human Fab antibody fragments from osteosarcoma patients. Generally, total RNA was obtained from circulating blood lymphocytes (*Id.*). Recombinant Fab were cloned from the μ, γ and κ chain antibody repertoires and inserted into a phage display library (*Id.*). RNAs were converted to cDNAs and used to make Fab cDNA libraries using specific primers against the heavy and light chain immunoglobulin sequences (Marks et al., 1991, *J. Mol. Biol.* 222:581-97, incorporated herein by reference). Library construction was performed according to Andris-Widhopf et al. (2000, In: *Phage Display Laboratory Manual*, Barbas et al. (eds), 1st edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY pp. 9.1 to 9.22, incorporated herein by reference). The final Fab fragments were digested with restriction endonucleases and inserted into the bacteriophage genome to make the phage display library. Such libraries may be screened by standard phage display methods, as known in the art. The skilled artisan will realize that this technique is exemplary only and any known method for making and screening human antibodies or antibody fragments by phage display may be utilized.

[0102] In another alternative, transgenic animals that have been genetically engineered to produce human antibodies may be used to generate antibodies against essentially any immunogenic target, using standard immunization protocols. A non-limiting example of such a system is the XenoMouse® (*e.g.*, Green et al., 1999, *J. Immunol. Methods* 231:11-23, incorporated herein by reference) from Abgenix (Fremont, CA). In the XenoMouse® and similar animals, the mouse antibody genes have been inactivated and replaced by functional human antibody genes, while the remainder of the mouse immune system remains intact.

[0103] The XenoMouse® was transformed with germline-configured YACs (yeast artificial chromosomes) that contained portions of the human IgH and Igkappa loci, including the majority of the variable region sequences, along accessory genes and regulatory sequences. The human variable region repertoire may be used to generate antibody producing B cells, which may be processed into hybridomas by known techniques. A XenoMouse® immunized with a target antigen will produce human antibodies by the normal immune response, which may be harvested and/or produced by standard techniques discussed above. A variety of strains of XenoMouse® are available, each of which is capable of producing a different class

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of antibody. Such human antibodies may be coupled to other molecules by chemical cross-linking or other known methodologies. Transgenically produced human antibodies have been shown to have therapeutic potential, while retaining the pharmacokinetic properties of normal human antibodies (Green et al., 1999). The skilled artisan will realize that the claimed compositions and methods are not limited to use of the XenoMouse® system but may utilize any transgenic animal that has been genetically engineered to produce human antibodies.

Pre-Targeting

[0104] One strategy for use of bi-specific stably tethered constructs includes pre-targeting methodologies, in which an effector molecule is administered to a subject after a bi-specific construct has been administered. The bi-specific construct, which would include a binding site for an effector, hapten or carrier and one for the diseased tissue, localizes to the diseased tissue and increases the specificity of localization of the effector to the diseased tissue (U.S. Patent Application No. 20050002945). Because the effector molecule may be cleared from circulation much more rapidly than the bi-specific construct, normal tissues may have a decreased exposure to the effector molecule when a pre-targeting strategy is used than when the effector molecule is directly linked to the disease targeting antibody.

[0105] Pre-targeting methods have been developed to increase the target:background ratios of detection or therapeutic agents. Examples of pre-targeting and biotin/avidin approaches are described, for example, in Goodwin et al., U.S. Pat. No. 4,863,713; Goodwin et al., J. Nucl. Med. 29:226, 1988; Hnatowich et al., J. Nucl. Med. 28:1294, 1987; Oehr et al., J. Nucl. Med. 29:728, 1988; Klibanov et al., J. Nucl. Med. 29:1951, 1988; Sinitsyn et al., J. Nucl. Med. 30:66, 1989; Kalofonos et al., J. Nucl. Med. 31:1791, 1990; Schechter et al., Int. J. Cancer 48:167, 1991; Paganelli et al., Cancer Res. 51:5960, 1991; Paganelli et al., Nucl. Med. Commun. 12:211, 1991; U.S. Pat. No. 5,256,395; Stickney et al., Cancer Res. 51:6650, 1991; Yuan et al., Cancer Res. 51:3119, 1991; U.S. Pat. No. 6,077,499; U.S. Ser. No. 09/597,580; U.S. Ser. No. 10/361,026; U.S. Ser. No. 09/337,756; U.S. Ser. No. 09/823,746; U.S. Ser. No. 10/116,116; U.S. Ser. No. 09/382,186; U.S. Ser. No. 10/150,654; U.S. Pat. No. 6,090,381; U.S. Pat. No. 6,472,511; U.S. Ser. No. 10/114,315; U.S. Provisional Application No. 60/386,411; U.S. Provisional Application No. 60/345,641; U.S. Provisional Application No. 60/3328,835; U.S. Provisional Application No. 60/426,379; U.S. Ser. No. 09/823,746; U.S. Ser. No. 09/337,756; and U.S. Provisional Application No. 60/342,103, all of which are incorporated herein by reference.

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[0106] In certain embodiments, bi-specific constructs and targetable constructs may be of use in treating and/or imaging normal or diseased tissue and organs, for example using the methods described in U.S. Pat. Nos. 6,126,916; 6,077,499; 6,010,680; 5,776,095; 5,776,094; 5,776,093; 5,772,981; 5,753,206; 5,746,996; 5,697,902; 5,328,679; 5,128,119; 5,101,827; and 4,735,210, each incorporated herein by reference. Additional methods are described in U.S. application Ser. No. 09/337,756 filed Jun. 22, 1999 and in U.S. application Ser. No. 09/823,746, filed Apr. 3, 2001.

Aptamers

[0107] In certain embodiments, a precursor for construct formation may comprise an aptamer. Methods of constructing and determining the binding characteristics of aptamers are well known in the art. For example, such techniques are described in U.S. Patent Nos. 5,582,981, 5,595,877 and 5,637,459, each incorporated herein by reference.

[0108] Aptamers may be prepared by any known method, including synthetic, recombinant, and purification methods, and may be used alone or in combination with other ligands specific for the same target. In general, a minimum of approximately 3 nucleotides, preferably at least 5 nucleotides, are necessary to effect specific binding. Aptamers of sequences shorter than 10 bases may be feasible, although aptamers of 10, 20, 30 or 40 nucleotides may be preferred.

[0109] Aptamers need to contain the sequence that confers binding specificity, but may be extended with flanking regions and otherwise derivatized. In preferred embodiments, the binding sequences of aptamers may be flanked by primer-binding sequences, facilitating the amplification of the aptamers by PCR or other amplification techniques. In a further embodiment, the flanking sequence may comprise a specific sequence that preferentially recognizes or binds a moiety to enhance the immobilization of the aptamer to a substrate.

[0110] Aptamers may be isolated, sequenced, and/or amplified or synthesized as conventional DNA or RNA molecules. Alternatively, aptamers of interest may comprise modified oligomers. Any of the hydroxyl groups ordinarily present in aptamers may be replaced by phosphonate groups, phosphate groups, protected by a standard protecting group, or activated to prepare additional linkages to other nucleotides, or may be conjugated to solid supports. One or more phosphodiester linkages may be replaced by alternative linking groups, such as P(O)O replaced by P(O)S, P(O)NR$_2$, P(O)R, P(O)OR', CO, or CNR$_2$, wherein

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R is H or alkyl (1-20C) and R' is alkyl (1-20C); in addition, this group may be attached to adjacent nucleotides through O or S. Not all linkages in an oligomer need to be identical.

[0111] Methods for preparation and screening of aptamers that bind to particular targets of interest are well known, for example U.S. Pat. No. 5,475,096 and U.S. Pat. No. 5,270,163, each incorporated by reference. The technique generally involves selection from a mixture of candidate aptamers and step-wise iterations of binding, separation of bound from unbound aptamers and amplification. Because only a small number of sequences (possibly only one molecule of aptamer) corresponding to the highest affinity aptamers exist in the mixture, it is generally desirable to set the partitioning criteria so that a significant amount of aptamers in the mixture (approximately 5-50%) is retained during separation. Each cycle results in an enrichment of aptamers with high affinity for the target. Repetition for between three to six selection and amplification cycles may be used to generate aptamers that bind with high affinity and specificity to the target.

Avimers

[0112] In certain embodiments, the precursors, components and/or complexes described herein may comprise one or more avimer sequences. Avimers are a class of binding proteins somewhat similar to antibodies in their affinities and specificities for various target molecules. They were developed from human extracellular receptor domains by *in vitro* exon shuffling and phage display. (Silverman et al., 2005, Nat. Biotechnol. 23:1493-94; Silverman et al., 2006, Nat. Biotechnol. 24:220.) The resulting multidomain proteins may comprise multiple independent binding domains that may exhibit improved affinity (in some cases sub-nanomolar) and specificity compared with single-epitope binding proteins. (*Id.*) In various embodiments, avimers may be attached to, for example, DDD sequences for use in the claimed methods and compositions. Additional details concerning methods of construction and use of avimers are disclosed, for example, in U.S. Patent Application Publication Nos. 20040175756, 20050048512, 20050053973, 20050089932 and 20050221384, the Examples section of each of which is incorporated herein by reference.

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Methods of Disease Tissue Detection, Diagnosis and Imaging

Protein-Based In Vitro Diagnosis

[0113] The present invention contemplates the use of stably tethered structures to screen biological samples *in vitro* and/or *in vivo* for the presence of the disease-associated antigens. In exemplary immunoassays, a stably tethered structure comprising an antibody, fusion protein, or fragment thereof may be utilized in liquid phase or bound to a solid-phase carrier, as described below. In preferred embodiments, particularly those involving *in vivo* administration, the antibody or fragment thereof is humanized. Also preferred, the antibody or fragment thereof is fully human. Still more preferred, the fusion protein comprises a humanized or fully human antibody. The skilled artisan will realize that a wide variety of techniques are known for determining levels of expression of a particular gene and any such known method, such as immunoassay, RT-PCR, mRNA purification and/or cDNA preparation followed by hybridization to a gene expression assay chip may be utilized to determine levels of expression in individual subjects and/or tissues. Exemplary in vitro assays of use include RIA, ELISA, sandwich ELISA, Western blot, slot blot, dot blot, and the like. Although such techniques were developed using intact antibodies, stably tethered structures that incorporate antibodies, antibody fragments or other binding moieties may be used.

[0114] Stably tethered structures incorporating antibodies, fusion proteins, antibody fragments and/or other binding moieties may also be used to detect the presence of a target antigen in tissue sections prepared from a histological specimen. Such in situ detection can be used to determine the presence of the antigen and to determine the distribution of the antigen in the examined tissue. In situ detection can be accomplished by applying a detectably-labeled structure to frozen or paraffin-embedded tissue sections. General techniques of in situ detection are well-known to those of ordinary skill. See, for example, Ponder, "Cell Marking Techniques and Their Application," in MAMMALIAN DEVELOPMENT: A PRACTICAL APPROACH 113-38 Monk (ed.) (IRL Press 1987), and Coligan at pages 5.8.1-5.8.8.

[0115] Stably tethered structures can be detectably labeled with any appropriate marker moiety, for example, a radioisotope, an enzyme, a fluorescent label, a dye, a chromogen, a chemiluminescent label, a bioluminescent label or a paramagnetic label.

[0116] The marker moiety may be a radioisotope that is detected by such means as the use of a gamma counter or a beta-scintillation counter or by autoradiography. In a preferred

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embodiment, the diagnostic conjugate is a gamma-, beta- or a positron-emitting isotope. A marker moiety refers to a molecule that will generate a signal under predetermined conditions. Examples of marker moieties include radioisotopes, enzymes, fluorescent labels, chemiluminescent labels, bioluminescent labels and paramagnetic labels. The binding of marker moieties to stably tethered structures can be accomplished using standard techniques known to the art. Typical methodology in this regard is described by Kennedy et al., Clin. Chim. Acta 70: 1 (1976), Schurs et al., Clin. Chim. Acta 81: 1 (1977), Shih et al., Int'l J. Cancer 46: 1101 (1990).

Nucleic Acid Based In Vitro Diagnosis

[0117] Stably tethered structures may, in some embodiments, incorporated nucleic acid moieties. In particular embodiments, nucleic acids may be analyzed to determine levels of binding, particularly using nucleic acid amplification methods. Various forms of amplification are well known in the art and any such known method may be used. Generally, amplification involves the use of one or more primers that hybridize selectively or specifically to a target nucleic acid sequence to be amplified.

[0118] The term primer, as defined herein, is meant to encompass any nucleic acid that is capable of priming the synthesis of a nascent nucleic acid in a template-dependent process. Computerized programs for selection and design of amplification primers are available from commercial and/or public sources well known to the skilled artisan. A number of template dependent processes are available to amplify the marker sequences present in a given sample. One of the best-known amplification methods is the polymerase chain reaction (referred to as PCR), which is described in detail in U.S. Patent Nos. 4,683,195, 4,683,202 and 4,800,159. However, other methods of amplification are known and may be used.

In Vivo Diagnosis

[0119] Methods of diagnostic imaging with labeled peptides or MAbs are well-known. For example, in the technique of immunoscintigraphy, ligands or antibodies are labeled with a gamma-emitting radioisotope and introduced into a patient. A gamma camera is used to detect the location and distribution of gamma-emitting radioisotopes. See, for example, Srivastava (ed.), RADIOLABELED MONOCLONAL ANTIBODIES FOR IMAGING AND THERAPY (Plenum Press 1988), Chase, "Medical Applications of Radioisotopes," in REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition, Gennaro et al. (eds.), pp. 624-652 (Mack Publishing Co., 1990), and Brown, "Clinical Use of Monoclonal Antibodies,"

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in BIOTECHNOLOGY AND PHARMACY 227-49, Pezzuto et al. (eds.) (Chapman & Hall 1993). Also preferred is the use of positron-emitting radionuclides (PET isotopes), such as with an energy of 511 keV, such as ^{18}F, ^{68}Ga, ^{64}Cu, and ^{124}I. Such imaging can be conducted by direct labeling of the stably tethered structure, or by a pretargeted imaging method, as described in Goldenberg et al, "Antibody Pre-targeting Advances Cancer Radioimmunodetection and Radioimmunotherapy," (J Clin Oncol 2006;24:823-834), see also U.S. Patent Publication Nos. 20050002945, 20040018557, 20030148409 and 20050014207, each incorporated herein by reference.

[0120] The radiation dose delivered to the patient is maintained at as low a level as possible through the choice of isotope for the best combination of minimum half-life, minimum retention in the body, and minimum quantity of isotope which will permit detection and accurate measurement. Examples of radioisotopes that are appropriate for diagnostic imaging include ^{99m}Tc and ^{111}In.

[0121] The stably tethered structures, or haptens or carriers that bind to them, also can be labeled with paramagnetic ions and a variety of radiological contrast agents for purposes of *in vivo* diagnosis. Contrast agents that are particularly useful for magnetic resonance imaging comprise gadolinium, manganese, dysprosium, lanthanum, or iron ions. Additional agents include chromium, copper, cobalt, nickel, rhenium, europium, terbium, holmium, or neodymium. ligands, antibodies and fragments thereof can also be conjugated to ultrasound contrast/enhancing agents. For example, one ultrasound contrast agent is a liposome that comprises a humanized IgG or fragment thereof. Also preferred, the ultrasound contrast agent is a liposome that is gas filled.

Imaging agents and radioisotopes

[0122] Many appapriate imaging agents are known in the art, as are methods for their attachment to proteins or peptides (see, e.g., U.S. patents 5,021,236 and 4,472,509, both incorporated herein by reference). Certain attachment methods involve the use of a metal chelate complex employing, for example, an organic chelating agent such a DTPA attached to the protein or peptide (U.S. Patent 4,472,509). Proteins or peptides also may be reacted with an enzyme in the presence of a coupling agent such as glutaraldehyde or periodate. Conjugates with fluorescein markers are prepared in the presence of these coupling agents or by reaction with an isothiocyanate.

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[0123] Non-limiting examples of paramagnetic ions of potential use as imaging agents include chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysprosium (III), holmium (III) and erbium (III), with gadolinium being particularly preferred. Ions useful in other contexts, such as X-ray imaging, include but are not limited to lanthanum (III), gold (III), lead (II), and especially bismuth (III).

[0124] Radioisotopes of potential use as imaging or therapeutic agents include astatine[211], carbon[14], chromium[51], chlorine[36], cobalt[57], cobalt[58], copper[62], copper[64], copper[67], Eu[152], fluorine[18], gallium[67], gallium[68], hydrogen[3], iodine[123], iodine[124], iodine[125], iodine[131], indium[111], iron[52], iron[59], lutetium[177], phosphorus32, phosphorus[33], rhenium[186], rhenium[188], Sc[47], selenium[75], silver[111], sulphur[35], technetium[94m], technetium[99m], yttrium[86] and yttrium[90], and zirconium[89]. I[125] is often being preferred for use in certain embodiments, and technetium[99m] and indium[111] are also often preferred due to their low energy and suitability for long-range detection.

[0125] Radioactively labeled proteins or peptides may be produced according to well-known methods in the art. For instance, they can be iodinated by contact with sodium or potassium iodide and a chemical oxidizing agent such as sodium hypochlorite, or an enzymatic oxidizing agent, such as lactoperoxidase. Proteins or peptides may be labeled with technetium-[99m] by ligand exchange process, for example, by reducing pertechnate with stannous solution, chelating the reduced technetium onto a Sephadex column and applying the peptide to this column or by direct labeling techniques, e.g., by incubating pertechnate, a reducing agent such as $SNCl_2$, a buffer solution such as sodium-potassium phthalate solution, and the peptide. Intermediary functional groups which are often used to bind radioisotopes which exist as metallic ions to peptides include diethylenetriaminepentaacetic acid (DTPA), DOTA, NOTA, porphyrin chelators and ethylene diaminetetracetic acid (EDTA). Also contemplated for use are fluorescent labels, including rhodamine, fluorescein isothiocyanate and renographin.

[0126] In certain embodiments, the proteins or peptides may be linked to a secondary binding ligand or to an enzyme (an enzyme tag) that will generate a colored product upon contact with a chromogenic substrate. Examples of suitable enzymes include urease, alkaline phosphatase, (horseradish) hydrogen peroxidase and glucose oxidase. Preferred secondary binding ligands are biotin and avidin or streptavidin compounds. The use of such labels is well known to those of skill in the art in light and is described, for example, in U.S. Patents

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3,817,837; 3,850,752; 3,939,350; 3,996,345; 4,277,437; 4,275,149 and 4,366,241; each

incorporated herein by reference. These fluorescent labels are preferred for in vitro uses, but

may also be of utility in *in vivo* applications, particularly endoscopic or intravascular

detection procedures.

[0127] In alternative embodiments, ligands, antibodies, or other proteins or peptides may be

tagged with a fluorescent marker. Non-limiting examples of photodetectable labels include

Alexa 350, Alexa 430, AMCA, aminoacridine, BODIPY 630/650, BODIPY 650/665,

BODIPY-FL, BODIPY-R6G, BODIPY-TMR, BODIPY-TRX, 5-carboxy-4',5'-dichloro-2',7'-

dimethoxy fluorescein, 5-carboxy-2',4',5',7'-tetrachlorofluorescein, 5-carboxyfluorescein, 5-

carboxyrhodamine, 6-carboxyrhodamine, 6-carboxytetramethyl amino, Cascade Blue, Cy2,

Cy3, Cy5,6-FAM, dansyl chloride, Fluorescein, HEX, 6-JOE, NBD (7-nitrobenz-2-oxa-1,3-

diazole), Oregon Green 488, Oregon Green 500, Oregon Green 514, Pacific Blue, phthalic

acid, terephthalic acid, isophthalic acid, cresyl fast violet, cresyl blue violet, brilliant cresyl

blue, para-aminobenzoic acid, erythrosine, phthalocyanines, azomethines, cyanines,

xanthines, succinylfluoresceins, rare earth metal cryptates, europium trisbipyridine diamine, a

europium cryptate or chelate, diamine, dicyanins, La Jolla blue dye, allopycocyanin,

allococyanin B, phycocyanin C, phycocyanin R, thiamine, phycoerythrocyanin,

phycoerythrin R, REG, Rhodamine Green, rhodamine isothiocyanate, Rhodamine Red, ROX,

TAMRA, TET, TRIT (tetramethyl rhodamine isothiol), Tetramethylrhodamine, Edans and

Texas Red. These and other luminescent labels may be obtained from commercial sources

such as Molecular Probes (Eugene, OR), and EMD Biosciences (San Diego, CA).

[0128] Chemiluminescent labeling compounds of use may include luminol, isoluminol, an

aromatic acridinium ester, an imidazole, an acridinium salt and an oxalate ester, or a

bioluminescent compound such as luciferin, luciferase and aequorin. Diagnostic conjugates

may be used, for example, in intraoperative, endoscopic, or intravascular tumor or disease

diagnosis.

[0129] In various embodiments, labels of use may comprise metal nanoparticles. Methods of

preparing nanoparticles are known. (*See e.g.*, U.S. Patent Nos. 6,054,495; 6,127,120;

6,149,868; Lee and Meisel, *J. Phys. Chem.* 86:3391-3395, 1982.) Nanoparticles may also

be obtained from commercial sources (*e.g.*, Nanoprobes Inc., Yaphank, NY; Polysciences,

Inc., Warrington, PA). Modified nanoparticles are available commercially, such as

Nanogold® nanoparticles from Nanoprobes, Inc. (Yaphank, NY). Functionalized

nanoparticles of use for conjugation to proteins or peptides may be commercially obtained.

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Therapeutic agents

Pharmaceutical Compositions

[0130] In some embodiments, a stably tethered structure and/or one or more other therapeutic agents may be administered to a subject, such as a subject with cancer. Such agents may be administered in the form of pharmaceutical compositions. Generally, this will entail preparing compositions that are essentially free of impurities that could be harmful to humans or animals. One skilled in the art would know that a pharmaceutical composition can be administered to a subject by various routes including, for example, orally or parenterally, such as intravenously.

[0131] In certain embodiments, an effective amount of a therapeutic agent must be administered to the subject. An "effective amount" is the amount of the agent that produces a desired effect. An effective amount will depend, for example, on the efficacy of the agent and on the intended effect. For example, a lesser amount of an antiangiogenic agent may be required for treatment of a hyperplastic condition, such as macular degeneration or endometriosis, compared to the amount required for cancer therapy in order to reduce or eliminate a solid tumor, or to prevent or reduce its metastasizing. An effective amount of a particular agent for a specific purpose can be determined using methods well known to those in the art.

Chemotherapeutic Agents

[0132] In certain embodiments, chemotherapeutic agents may be administered. Anti-cancer chemotherapeutic agents of use include, but are not limited to, 5-fluorouracil, bleomycin, busulfan, camptothecins, carboplatin, chlorambucil, cisplatin (CDDP), cyclophosphamide, dactinomycin, daunorubicin, doxorubicin, estrogen receptor binding agents, etoposide (VP16), farnesyl-protein transferase inhibitors, gemcitabine, ifosfamide, mechlorethamine, melphalan, methotrexate, mitomycin, navelbine, nitrosurea, plicomycin, procarbazine, raloxifene, tamoxifen, taxol, temazolomide (an aqueous form of DTIC), transplatinum, vinblastine and methotrexate, vincristine, or any analog or derivative variant of the foregoing. Chemotherapeutic agents of use against infectious organisms include, but are not limited to, acyclovir, albendazole, amantadine, amikacin, amoxicillin, amphotericin B, ampicillin, aztreonam, azithromycin, bacitracin, bactrim, Batrafen®, bifonazole, carbenicillin, caspofungin, cefaclor, cefazolin, cephalosporins, cefepime, ceftriaxone, cefotaxime, chloramphenicol, cidofovir, Cipro®, clarithromycin, clavulanic acid, clotrimazole,

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cloxacillin, doxycycline, econazole, erythrocycline, erythromycin, flagyl, fluconazole, flucytosine, foscarnet, furazolidone, ganciclovir, gentamycin, imipenem, isoniazid, itraconazole, kanamycin, ketoconazole, lincomycin, linezolid, meropenem, miconazole, minocycline, naftifine, nalidixic acid, neomycin, netilmicin, nitrofurantoin, nystatin, oseltamivir, oxacillin, paromomycin, penicillin, pentamidine, piperacillin-tazobactam, rifabutin, rifampin, rimantadine, streptomycin, sulfamethoxazole, sulfasalazine, tetracycline, tioconazole, tobramycin, tolciclate, tolnaftate, trimethoprim sulfamethoxazole, valacyclovir, vancomycin, zanamir, and zithromycin.

[0133] Chemotherapeutic agents and methods of administration, dosages, etc., are well known to those of skill in the art (see for example, the "Physicians Desk Reference", Goodman & Gilman's "The Pharmacological Basis of Therapeutics" and in "Remington's Pharmaceutical Sciences", incorporated herein by reference in relevant parts). Some variation in dosage will necessarily occur depending on the condition of the subject being treated. The person responsible for administration will, in any event, determine the appropriate dose for the individual subject.

Hormones

[0134] Corticosteroid hormones can increase the effectiveness of other chemotherapy agents, and consequently, they are frequently used in combination treatments. Prednisone and dexamethasone are examples of corticosteroid hormones. Progestins, such as hydroxyprogesterone caproate, medroxyprogesterone acetate, and megestrol acetate, have been used in cancers of the endometrium and breast. Estrogens such as diethylstilbestrol and ethinyl estradiol have been used in cancers such as prostate cancer. Antiestrogens such as tamoxifen have been used in cancers such as breast cancer. Androgens such as testosterone propionate and fluoxymesterone have also been used in treating breast cancer.

Angiogenesis inhibitors

[0135] In certain embodiments, anti-angiogenic agents, such as angiostatin, baculostatin, canstatin, maspin, anti-VEGF antibodies, anti-PlGF peptides and antibodies, anti-vascular growth factor antibodies, anti-Flk-1 antibodies, anti-Flt-1 antibodies and peptides, laminin peptides, fibronectin peptides, plasminogen activator inhibitors, tissue metalloproteinase inhibitors, interferons, interleukin-12, IP-10, Gro-ß, thrombospondin, 2-methoxyoestradiol, proliferin-related protein, carboxiamidotriazole, CM101, Marimastat, pentosan polysulphate, angiopoietin-2, interferon-alpha, herbimycin A, PNU145156E, 16K prolactin fragment,

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Linomide, thalidomide, pentoxifylline, genistein, TNP-470, endostatin, paclitaxel, accutin, angiostatin, cidofovir, vincristine, bleomycin, AGM-1470, platelet factor 4 or minocycline may be of use.

Immunomodulators

[0136] As used herein, the term "immunomodulator" includes cytokines, stem cell growth factors, lymphotoxins and hematopoietic factors, such as interleukins, colony-stimulating factors, interferons (e.g., interferons-α, -ß and -γ) and the stem cell growth factor designated "S1 factor." Examples of suitable immunomodulator moieties include IL-2, IL-6, IL-10, IL-12, IL-18, IL-21, interferon-gamma, TNF-alpha, and the like.

[0137] The term "cytokine" is a generic term for proteins or peptides released by one cell population which act on another cell as intercellular mediators. As used broadly herein, examples of cytokines include lymphokines, monokines, growth factors and traditional polypeptide hormones. Included among the cytokines are growth hormones such as human growth hormone, N-methionyl human growth hormone, and bovine growth hormone; parathyroid hormone; thyroxine; insulin; proinsulin; relaxin; prorelaxin; glycoprotein hormones such as follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), and luteinizing hormone (LH); hepatic growth factor; prostaglandin, fibroblast growth factor; prolactin; placental lactogen, OB protein; tumor necrosis factor-α and - ß; mullerian-inhibiting substance; mouse gonadotropin-associated peptide; inhibin; activin; vascular endothelial growth factor; integrin; thrombopoietin (TPO); nerve growth factors such as NGF-ß; platelet-growth factor; transforming growth factors (TGFs) such as TGF- α and TGF-ß; insulin-like growth factor-I and -II; erythropoietin (EPO); osteoinductive factors; interferons such as interferon-α, -β, and -γ; colony stimulating factors (CSFs) such as macrophage-CSF (M-CSF); granulocyte-macrophage-CSF (GM-CSF); and granulocyte-CSF (G-CSF); interleukins (ILs) such as IL-1, IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12; IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, LIF, G-CSF, GM-CSF, M-CSF, EPO, kit-ligand or FLT-3, angiostatin, thrombospondin, endostatin, tumor necrosis factor and LT. As used herein, the term cytokine includes proteins from natural sources or from recombinant cell culture and biologically active equivalents of the native sequence cytokines.

[0138] Chemokines generally act as chemoattractants to recruit immune effector cells to the site of chemokine expression. Chemokines include, but are not limited to, RANTES, MCAF,

MIP1-alpha, MIP1-Beta, and IP-10. The skilled artisan will recognize that certain cytokines are also known to have chemoattractant effects and could also be classified under the term chemokines. Similarly, the terms immunomodulator and cytokine overlap in their respective members.

Radioisotope therapy and Radioimmunotherapy

[0139] In some embodiments, the peptides and/or proteins may be of use in radionuclide therapy or radioimmunotherapy methods (see, e.g., Govindan et al., 2005, *Technology in Cancer Research & Treatment*, 4:375-91; Sharkey and Goldenberg, 2005, *J. Nucl. Med.* 46:115S-127S; Goldenberg et al. (J Clin Oncol 2006; 24:823-834), "Antibody Pre-targeting Advances Cancer Radioimmunodetection and Radioimmunotherapy," each incorporated herein by reference.) In specific embodiments, stably tethered structures may be directly tagged with a radioisotope of use and administered to a subject. In alternative embodiments, radioisotope(s) may be administered in a pre-targeting method as discussed above, using a haptenic peptide or ligand that is radiolabeled and injected after administration of a bispecific stably tethered structure that localizes at the site of elevated expression in the diseased tissue.

[0140] Radioactive isotopes useful for treating diseased tissue include, but are not limited to- ^{111}In, ^{177}Lu, ^{212}Bi, ^{213}Bi, ^{211}At, ^{62}Cu, ^{67}Cu, ^{90}Y, ^{125}I, ^{131}I, ^{32}P, ^{33}P, ^{47}Sc, ^{111}Ag, ^{67}Ga, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{166}Dy, ^{166}Ho, ^{186}Re, ^{188}Re, ^{189}Re, ^{212}Pb, ^{223}Ra, ^{225}Ac, ^{59}Fe, ^{75}Se, ^{77}As, ^{89}Sr, ^{99}Mo, ^{105}Rh, ^{109}Pd, ^{143}Pr, ^{149}Pm, ^{169}Er, ^{194}Ir, ^{198}Au, ^{199}Au, and ^{211}Pb. The therapeutic radionuclide preferably has a decay energy in the range of 20 to 6,000 keV, preferably in the ranges 60 to 200 keV for an Auger emitter, 100-2,500 keV for a beta emitter, and 4,000-6,000 keV for an alpha emitter. Maximum decay energies of useful beta-particle-emitting nuclides are preferably 20-5,000 keV, more preferably 100-4,000 keV, and most preferably 500-2,500 keV. Also preferred are radionuclides that substantially decay with Auger-emitting particles. For example, Co-58, Ga-67, Br-80m, Tc-99m, Rh-103m, Pt-109, In-111, Sb-119, 1-125, Ho-161, Os-189m and Ir-192. Decay energies of useful beta-particle-emitting nuclides are preferably <1,000 keV, more preferably <100 keV, and most preferably <70 keV. Also preferred are radionuclides that substantially decay with generation of alpha-particles. Such radionuclides include, but are not limited to: Dy-152, At-211, Bi-212, Ra-223, Rn-219, Po-215, Bi-211, Ac-225, Fr-221, At-217, Bi-213 and Fm-255. Decay energies of useful alpha-particle-emitting radionuclides are preferably 2,000-10,000 keV, more preferably 3,000-8,000 keV, and most preferably 4,000-7,000 keV.

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[0141] For example, ^{67}Cu, considered one of the more promising radioisotopes for radioimmunotherapy due to its 61.5 hour half-life and abundant supply of beta particles and gamma rays, can be conjugated to a protein or peptide using the chelating agent, p-bromoacetamido-benzyl-tetraethylaminetetraacetic acid (TETA). Alternatively, ^{90}Y, which emits an energetic beta particle, can be coupled to a peptide, antibody, fusion protein, or fragment thereof, using diethylenetriaminepentaacetic acid (DTPA).

[0142] Additional potential radioisotopes include ^{11}C, ^{13}N, ^{15}O, ^{75}Br, ^{198}Au, ^{224}Ac, ^{126}I, ^{133}I, ^{77}Br, ^{113m}In, ^{95}Ru, ^{97}Ru, ^{103}Ru, ^{105}Ru, ^{107}Hg, ^{203}Hg, ^{121m}Te, ^{122m}Te, ^{125m}Te, ^{165}Tm, ^{167}Tm, ^{168}Tm, ^{197}Pt, ^{109}Pd, ^{105}Rh, ^{142}Pr, ^{143}Pr, ^{161}Tb, ^{166}Ho, ^{199}Au, ^{57}Co, ^{58}Co, ^{51}Cr, ^{59}Fe, ^{75}Se, ^{201}Tl, ^{225}Ac, ^{76}Br, ^{169}Yb, and the like.

[0143] In another embodiment, a radiosensitizer can be used. The addition of the radiosensitizer can result in enhanced efficacy. Radiosensitizers are described in D. M. Goldenberg (ed.), CANCER THERAPY WITH RADIOLABELED ANTIBODIES, CRC Press (1995), which is incorporated herein by reference in its entirety.

[0144] The peptide, antibody, antibody fragment, or fusion protein that has a boron addend-loaded carrier for thermal neutron activation therapy will normally be effected in similar ways. However, it will be advantageous to wait until non-targeted immunoconjugate clears before neutron irradiation is performed. Clearance can be accelerated using an antibody that binds to the ligand. See U.S. Pat. No. 4,624,846 for a description of this general principle. For example, boron addends such as carboranes, can be attached to antibodies. Carboranes can be prepared with carboxyl functions on pendant side chains, as is well-known in the art. Attachment of carboranes to a carrier, such as aminodextran, can be achieved by activation of the carboxyl groups of the carboranes and condensation with amines on the carrier. The intermediate conjugate is then conjugated to the antibody. After administration of the conjugate, a boron addend is activated by thermal neutron irradiation and converted to radioactive atoms which decay by alpha-emission to produce highly toxic, short-range effects.

Kits

[0145] Various embodiments may concern kits containing components suitable for treating or diagnosing diseased tissue in a patient. Exemplary kits may contain at least one stably tethered structure. If the composition containing components for administration is not formulated for delivery via the alimentary canal, such as by oral delivery, a device capable of

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delivering the kit components through some other route may be included. One type of device, for applications such as parenteral delivery, is a syringe that is used to inject the composition into the body of a subject. Inhalation devices may also be used.

[0146] The kit components may be packaged together or separated into two or more separate containers. In some embodiments, the containers may be vials that contain sterile, lyophilized formulations of a composition that are suitable for reconstitution. A kit may also contain one or more buffers suitable for reconstitution and/or dilution of other reagents. Other containers that may be used include, but are not limited to, a pouch, tray, box, tube, or the like. Kit components may be packaged and maintained sterilely within the containers. Another component that can be included is instructions to a person using a kit for its use.

EXAMPLES

[0147] The following examples are provided to illustrate, but not to limit the claimed invention.

Example 1. General strategy for producing Fab-based subunits with the DDD1 sequence appended to either the C- or N-terminus of the Fd chain.

[0148] Fab-based subunits with the DDD1 sequence (SEQ ID NO:1) appended to either the C- or N-terminus of the Fd chain are produced as fusion proteins. The plasmid vector pdHL2 has been used to produce a number of antibodies and antibody-based constructs. See Gillies et al., J Immunol Methods (1989), 125:191-202; Losman et al., Cancer (Phila) (1997), 80:2660-6. The di-cistronic mammalian expression vector directs the synthesis of the heavy and light chains of IgG. The vector sequences are mostly identical for many different IgG-pdHL2 constructs, with the only differences existing in the variable domain (VH and VL) sequences. Using molecular biology tools known to those skilled in the art, these IgG-pdHL2 expression vectors can be converted into Fd-DDD1-pdHL2 or Fd-DDD2-pdHL2 expression vectors by replacing the coding sequences for the hinge, CH2 and CH3 domains of the heavy chain with a sequence encoding the first 4 residues of the hinge, a 14 residue Gly-Ser linker and the first 44 residues of human RIIα. The shuttle vector CH1-DDD1-pGemT was designed to facilitate the conversion of IgG-pdHL2 vectors (Figure 2a) to Fd-DDD1-pdHL2 vectors (Figure 2b), as described below.

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Generation of the shuttle vector CH1-DDD1-pGemT

Preparation of CH1

[0149] The CH1 domain was amplified by PCR using the pdHL2 plasmid vector as a template. The left PCR primer consists of the upstream (5') of the CH1 domain and a SacII restriction endonuclease site, which is 5' of the CH1 coding sequence. The right primer consists of the sequence coding for the first 4 residues of the hinge (PKSC) followed by GGGGS with the final two codons (GS) comprising a Bam HI restriction site.

5' of CH1 Left Primer

5'GAACCTCGCGGACAGTTAAG-3' (SEQ ID NO:4)

CH1+G₄S-Bam Right

5'GGATCCTCCGCCGCCGCAGCTCTTAGGTTTCTTGTCCACCTTGGTGTTGCTGG-3' (SEQ ID NO:5)

[0150] The 410 bp PCR amplimer was cloned into the pGemT PCR cloning vector (Promega, Inc.) and clones were screened for inserts in the T7 (5') orientation.

Construction of (G₄S)₂DDD1

[0151] A duplex oligonucleotide, designated (G₄S)₂DDD1, was synthesized by Sigma Genosys (Haverhill, UK) to code for the amino acid sequence of DDD1 (SEQ ID NO:1) preceded by 11 residues of the linker peptide, with the first two codons comprising a BamHI restriction site. A stop codon and an EagI restriction site are appended to the 3'end. The encoded polypeptide sequence is shown below.

GSGGGGSGGGGSHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:6)

[0152] The two oligonucleotides, designated RIIA1-44 top and RIIA1-44 bottom, which overlap by 30 base pairs on their 3' ends, were synthesized (Sigma Genosys) and combined to comprise the central 154 base pairs of the 174 bp DDD1 sequence. The oligonucleotides were annealed and subjected to a primer extension reaction with Taq polymerase.

RIIA1-44 top

5'GTGGCGGGTCTGGCGGAGGTGGCAGCCACATCCAGATCCCGCCGGGGCTCACG GAGCTGCTGCAGGGCTACACGGTGGAGGTGCTGCGACAG-3' (SEQ ID NO:7)

RIIA1-44 bottom

5'GCGCGAGCTTCTCTCAGGCGGGTGAAGTACTCCACTGCGAATTCGACGAGGTC
AGGCGGCTGCTGTCGCAGCACCTCCACCGTGTAGCCCTG-3' (SEQ ID NO:8)

[0153] Following primer extension, the duplex was amplified by PCR using the following
primers:

G4S Bam-Left

5'-GGATCCGGAGGTGGCGGGTCTGGCGGAGGT-3' (SEQ ID NO:9)

1-44 stop Eag Right

5'-CGGCCGTCAAGCGCGAGCTTCTCTCAGGCG-3' (SEQ ID NO:10)

[0154] This amplimer was cloned into pGemT and screened for inserts in the T7 (5')
orientation.

Ligating DDD1 with CH1

[0155] A 190 bp fragment encoding the DDD1 sequence was excised from pGemT with
BamHI and NotI restriction enzymes and then ligated into the same sites in CH1-pGemT to
generate the shuttle vector CH1-DDD1-pGemT.

Cloning CH1-DDD1 into pdHL2-based vectors

[0156] The sequence encoding CH1-DDD1 can be incorporated into any IgG construct in the
pdHL2 vector as follows. The entire heavy chain constant domain is replaced with CH1-
DDD1 by removing the SacII/EagI restriction fragment (CH1-CH3) from pdHL2 and
replacing it with the SacII/EagI fragment of CH1-DDD1, which is excised from the
respective pGemT shuttle vector.

[0157] It is noted that the location of DDD1 is not restricted to the carboxyl terminal end of
CH1 and can be placed at the amino terminal end of the VH domain, as shown in Example 2.

Example 2. Methods for generating a₂ constructs composed of two identical Fab
subunits stably linked via the DDD1 sequence fused to either the C- or N-terminus of
the Fd chain.

Construction of C-DDD1-Fd-hMN-14-pdHL2

[0158] C-DDD1-Fd-hMN-14-pdHL2 is an expression vector for producing an a₂ construct
that comprises two copies of a fusion protein in which the DDD1 sequence is linked to hMN-
14 Fab at the C-terminus of the Fd chain via a flexible peptide spacer (Figure 3). The plasmid
vector hMN14(I)-pdHL2, which has been used to produce hMN-14 IgG, was converted to C-

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DDD1-Fd-hMN-14-pdHL2 by digestion with SacII and EagI restriction endonucleases, to remove the fragment encoding the CH1-CH3 domains, and insertion of the CH1-DDD1 fragment, which was excised from the CH1-DDD1-SV3 shuttle vector with SacII and EagI.

Construction of N-DDD1-Fd-hMN-14-pdHL2

[0159] N-DDD1-Fd-hMN-14-pdHL2 is an expression vector for producing an a_2 construct that comprises two copies of a fusion protein in which the DDD1 sequence is linked to hMN-14 Fab at the N-terminus of the Fd chain via a flexible peptide spacer (Figure 4).

[0160] The expression vector was engineered as follows. The DDD1 domain was amplified by PCR using the two primers shown below.

DDD1 Nco Left

5' CCATGGGCAGCCACATCCAGATCCCGCC –3' (SEQ ID NO:11)

DDD1-G₄S Bam Right

5'GGATCCGCCACCTCCAGATCCTCCGCCGCCAGCGCGAGCTTCTCTCAGGCGGGT
G - 3' (SEQ ID NO:12)

[0161] As a result of the PCR, an NcoI restriction site and the coding sequence for part of the linker (G₄S)₂ containing a BamHI restriction were appended to the 5' and 3' ends, respectively. The 170 bp PCR amplimer was cloned into the pGemT vector and clones were screened for inserts in the T7 (5') orientation. The 194 bp insert was excised from the pGemT vector with NcoI and SalI restriction enzymes and cloned into the SV3 shuttle vector, which was prepared by digestion with those same enzymes, to generate the intermediate vector DDD1-SV3.

[0162] The hMN-14 Fd sequence was amplified by PCR using the oligonucleotide primers shown below.

hMN-14VH left G4S Bam

5'-GGATCCGGCGGAGGTGGCTCTGAGGTCCAACTGGTGGAGAGCGG-3' (SEQ ID NO:13)

CH1-C stop Eag

5'- CGGCCGTCAGCAGCTCTTAGGTTTCTTGTC –3' (SEQ ID NO:14)

[0163] As a result of the PCR, a BamHI restriction site and the coding sequence for part of the linker (G₄S) were appended to the 5' end of the amplimer. A stop codon and EagI restriction site was appended to the 3'end. The 1043 bp amplimer was cloned into pGemT.

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The hMN-14-Fd insert was excised from pGemT with BamHI and EagI restriction enzymes and then ligated with DDD1-SV3 vector, which was prepared by digestion with those same enzymes, to generate the construct N-DDD1-Fd-hMN-14-SV3.

[0164] The N-DDD1-hMN-14 Fd sequence was excised with XhoI and EagI restriction enzymes and the 1.28 kb insert fragment was ligated with a vector fragment that was prepared by digestion of C-DDD1-Fd-hMN-14-pdHL2 with those same enzymes. The final expression vector is N-DDD1-Fd-hMN-14-pDHL2.

Production, purification and characterization of N-DDD1-Fab-hMN-14 and C-DDD1-Fab-hMN-14

[0165] The C-DDD1-Fd-hMN-14-pdHL2 and N-DDD1-Fd-hMN-14-pdHL2 vectors were transfected into Sp2/0-derived myeloma cells by electroporation. C-DDD1-Fd-hMN-14-pdHL2 is a di-cistronic expression vector, which directs the synthesis and secretion of both hMN-14 kappa light chain and hMN-14 Fd-DDD1, which combine to form C-DDD1-hMN-14 Fab. N-DDD1-hMN-14-pdHL2 is a di-cistronic expression vector, which directs the synthesis and secretion of both hMN-14 kappa light chain and N-DDD1-Fd-hMN-14, which combine to form N-DDD1-Fab-hMN-14. Each fusion protein forms a stable homodimer via the interaction of the DDD1 domain.

[0166] Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 μM methotrexate (MTX). Clones were screened for protein expression by ELISA, using microtitre plates coated with WI2 (a rat anti-id monoclonal antibody to hMN-14) and detection with HRP-conjugated goat anti-human Fab. The initial productivity of the highest producing C-DDD1-Fab-hMN14 and N-DDD1-Fab-hMN14 clones was 60 mg/L and 6 mg/L, respectively.

[0167] Both fusion proteins are purified using affinity chromatography. AD1-C is a peptide that binds specifically to DDD1-containing a_2 constructs. The amino acid sequence of AD1-C (SEQ ID NO:3) is shown in Figure 5. AD1-C was coupled to Affigel following reaction of the sulfhydryl group with chloroacetic anhydride. Culture supernatants were concentrated approximately 10-fold by ultrafiltration before loading onto an AD1-C-affigel column. The column was washed to baseline with PBS and C-DDD1-Fab-hMN-14 was eluted with 0.1 M Glycine, pH 2.5. The one-step affinity purification yielded about 81 mg of C-DDD1-Fab-hMN-14 from 1.2 liters of roller bottle culture. SE-HPLC analysis (Figure 6) of the eluate shows a single protein peak with a retention time (8.7 min) consistent with a 107-kDa protein. The purity was also confirmed by reducing SDS-PAGE (Figure 7), showing only two

bands of molecular size expected for the two polypeptide constituents of C-DDD1-Fab-hMN-14.

[0168] N-DDD1-Fab-hMN-14 was purified as described above for C-DDD1-Fab-hMN-14, yielding 10 mg from 1.2 liters of roller bottle culture. SE-HPLC analysis (Figure 8) of the eluate shows a single protein peak with a retention time (8.77 min) similar to C-DDD1-Fab-hMN-14 and consistent with a 107 kDa protein. Reducing SDS-PAGE shows only two bands attributed to the polypeptide constituents of N-DDD1-Fab-hMN-14.

[0169] The binding activity of C-DDD1-Fab-hMN-14 was determined by SE-HPLC analysis of samples in which the test article was mixed with various amounts of WI2. A sample prepared by mixing WI2 Fab and C-DDD1-Fab-hMN-14 at a molar ratio of 0.75:1 showed three peaks, which were attributed to unbound C-DDD1-Fab-hMN14 (8.71 min.), C-DDD1-Fab-hMN-14 bound to one WI2 Fab (7.95 min.), and C-DDD1-Fab-hMN14 bound to two WI2 Fabs (7.37 min.). When a sample containing WI2 Fab and C-DDD1-Fab-hMN-14 at a molar ratio of 4 was analyzed, only a single peak at 7.36 minutes was observed. These results (Figure 9) demonstrate that C-DDD1-Fab-hMN-14 is dimeric and has two active binding sites. Very similar results (Figure 10) were obtained when this experiment was repeated with N-DDD1-Fab-hMN-14.

[0170] Competitive ELISA (Figures 11 and 12) demonstrated that C-DDD1-Fab-hMN-14 and N-DDD1-Fab-hMN-14 binds to CEA with similar avidity to hMN-14 IgG, and significantly stronger than monovalent hMN-14 Fab. ELISA plates were coated with a fusion protein containing the epitope (A3B3) of CEA to which hMN-14 binds specifically. C-DDD1-Fab-hMN-14 is stable in pooled human serum for at least 24 h without appreciable loss in immunoreactivity as shown in Figures 13 and 14. C-DDD1-Fab-hMN-14 has been evaluated in mice bearing human colorectal cancer xenografts (LS174T) and the results (Figures 15 and 16) were similar to those obtained for hBS14-1, which is also bivalent for binding to CEA.

Example 3. Methods for generating a₂ constructs composed of two identical Fab fusion proteins, each containing ranpirnase (Rap) and the DDD1 sequence linked to the N-terminus of the light chain and the C-terminus of the Fd chain, respectively.

Construction of Rap-hPAM4-Fd-DDD1-pdHL2

[0171] Rap-hPAM4-Fd-DDD1-pdHL2 is an expression vector for producing an a₂ construct that comprises two identical Fab fusion proteins, each containing ranpirnase (Rap) and the

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DDD1 sequence linked to the N-terminus of the light chain and the C-terminus of the Fd

chain, respectively. hPAM4 is a humanized monoclonal antibody specific for MUC-1. The

plasmid vector Rap-hPAM4-γ1-pdHL2 used for producing the immunotoxin referred to as

2L-Rap(N69Q)-hPAM4, which is composed of two molecules of Rap, each fused to the N-

terminus of the light chain of hPAM4, was digested with Sac2 and NgoM4 to remove the

fragment encoding the CH1-CH3 domains, followed by ligation of the CH1-DDD1 fragment,

which was excised from the plasmid vector C-DDD1-Fd-hMN-14-pdHL2 with Sac2 and

NgoM4 to generate Rap-hPAM4-Fd-DDD1-pdHL2.

Production, purification and characterization of Rap-hPAM4-Fab-DDD1

[0172] The Rap-hPAM4-Fd-DDD1-pdHL2 vector was transfected into NS0 myeloma cells

by electroporation. Rap-hPAM4-Fd-DDD1-pdHL2 is a di-cistronic expression vector, which

directs the synthesis and secretion of both Rap-fused hPAM4 light chain and hPAM4-Fd-

DDD1, which combine to form the Rap-Fab fusion protein. Each fusion protein forms a

stable homodimer, referred to as Rap-hPAM4-Fab-DDD1, via the interaction of the DDD1

domain.

[0173] Following electroporation, the cells were plated in 96-well tissue culture plates and

transfectant clones were selected with 0.05 μM methotrexate (MTX). Clones were screened

for protein expression by ELISA using microtitre plates coated with WS (a rat anti-id

monoclonal antibody to hPAM4) and probed with ML98-1 (a mouse monoclonal antibody to

Rap) and HRP-conjugated goat anti-mouse Fc.

[0174] Rap-hPAM4-Fab-DDD1 was purified as described above using an AD1-C-affigel

column. The initial productivity of the selected clone was about 0.5 mg per liter. SE-HPLC

analysis (Figure 17) of the affinity-purified Rap-hPAM4-Fab-DDD1 shows a single protein

peak with a retention time (8.15 min) consistent with the expected molecular mass of ~130

kDa. The binding affinity of Rap-hPAM4-Fab-DDD1 for WS was shown to be similar to that

of hPAM4 IgG (Figure 18).

Example 4. Methods for generating a₄ constructs composed of four identical Fab fusion proteins, each containing the DDD2 sequence linked to the N-terminus of the Fd chain via a peptide spacer.

Construction of N-DDD2-Fd-hMN-14-pdHL2

[0175] N-DDD2-Fd-hMN-14-pdHL2 is an expression vector for producing an a₄ construct,

referred to as the tetravalent N-DDD2-Fab-hMN-14 hereafter, that comprises four copies of a

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fusion protein in which the DDD2 sequence is appended to hMN-14 Fab at the N-terminus of the Fd chain via a flexible peptide spacer.

[0176] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides (DDD2 Top and DDD2 Bottom), which comprise residues 1 – 13 of DDD2, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 polynucleotide kinase (PNK), resulting in overhangs on the 5' and 3' ends that are compatible for ligation with DNA digested with the restriction endonucleases NcoI and PstI, respectively

DDD2 Top

5'CATGTGCGGCCACATCCAGATCCCGCCGGGGCTCACGGAGCTGCTGCA-3' (SEQ ID NO:15)

DDD2 Bottom

5'GCAGCTCCGTGAGCCCCGGCGGGATCTGGATGTGGCCGCA-3' (SEQ ID NO:16)

[0177] The duplex DNA was ligated with a vector fragment, DDD1-hMN14 Fd-SV3 that was prepared by digestion with NcoI and PstI, to generate the intermediate construct DDD2-hMN14 Fd-SV3. A 1.28 kb insert fragment, which contained the coding sequence for DDD2-hMN14 Fd, was excised from the intermediate construct with XhoI and EagI restriction endonucleases and ligated with hMN14-pdHL2 vector DNA that was prepared by digestion with those same enzymes. The final expression vector is N-DDD2-Fd-hMN-14-pdHL2.

Production, purification and characterization of the tetravalent N-DDD2-Fab-hMN-14

[0178] N-DDD2-Fd-hMN-14-pdHL2 vector was transfected into Sp/EEE myeloma cells by electroporation. The di-cistronic expression vector directs the synthesis and secretion of both hMN-14 kappa light chain and N-DDD2-Fd-hMN-14, which combine to form the Fab-based subunit N-DDD2-Fab-hMN14. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 µM methotrexate (MTX).

[0179] Clones were screened for protein expression by ELISA using microtitre plates coated with WI2 (hMN-14 anti-Id) and detection was achieved with goat anti-human Fab-HRP. The

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highest producing clones had an initial productivity of approximately 10 mg/L. A total of 16 mg of N-DDD2-hMN-14 was purified by protein L affinity chromatography from 1.8 liters of roller bottle culture. Culture supernatants were concentrated approximately 10-fold by ultrafiltration before loading onto a protein L column. The column was washed to baseline with PBS and N-DDD2-Fab-hMN14 was eluted with 1 mM EDTA, 0.1 M NaAc, pH 2.5 and immediately neutralized with Tris-HCl. SE-HPLC analysis (Figure 19) showed four protein peaks, two of which were subsequently attributed to the tetrameric a_4 (7.94 min) and dimeric a_2 (8.88 min) forms of N-DDD2-Fab-hMN-14 and the remaining two were the dimer and monomer of the *kappa* chain. Most of the tetrameric a_4 form in the mixture was converted to the dimeric a_2 form (Figure 20) upon adding a thiol reducing agent such as TCEP, suggesting that the tetrameric a_4 form apparently is composed of two dimeric a_2 structures linked through intermolecular disulfide bridges formed between the cysteines present in DDD2. It is noted that approximately 15% of the total N-DDD2-Fab-hMN-14 remains in the a_4 form following reduction, even with high TCEP concentrations and long reaction times, suggesting that other mechanisms such as domain swapping may contribute to the formation of the a_4 form, in addition to disulfide bridging. The tetravalent N-DDD2-Fab-hMN-14 was separated from other molecular forms by gel filtration chromatography using a Superdex –200 column.

Example 5. Methods for generating a_4 constructs composed of four identical Fab fusion proteins, each containing the DDD2 sequence linked to the C-terminus of the Fd chain via a peptide spacer.

<u>Construction of C-DDD2-Fd-hMN-14-pdHL2</u>

[0180] C-DDD2-Fd-hMN-14-pdHL2 is an expression vector for producing an a_4 construct, referred to as the tetravalent C-DDD2-Fab-hMN-14 hereafter, that comprises four copies of a fusion protein in which the DDD2 sequence is appended to hMN-14 Fab at the C-terminus of the Fd chain via a flexible peptide spacer.

[0181] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides, which comprise the coding sequence for part of the linker peptide (GGGGSGGGCG) and residues 1 – 13 of DDD2, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 PNK, resulting in overhangs on the 5' and 3' ends that are compatible for ligation with DNA digested with the restriction endonucleases BamHI and PstI, respectively.

G4S-DDD2 top

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5'GATCCGGAGGTGGCGGGTCTGGCGGAGGTTGCGGCCACATCCAGATCCCGCCG GGGCTCACGGAGCTGCTGCA-3' (SEQ ID NO:17)

G4S-DDD2 bottom

5'GCAGCTCCGTGAGCCCCGGCGGGATCTGGATGTGGCCGCAACCTCCGCCAGAC CCGCCACCTCCG-3' (SEQ ID NO:18)

[0182] The duplex DNA was ligated with the shuttle vector CH1-DDD1-pGemT, which was prepared by digestion with BamHI and PstI, to generate the shuttle vector CH1-DDD2-pGemT. A 507 bp fragment was excised from CH1-DDD2-pGemT with SacII and EagI and ligated with the IgG expression vector hMN14(I)-pdHL2, which was prepared by digestion with SacII and EagI. The final expression construct is C-DDD2-Fd-hMN-14-pdHL2.

Construction of C-DDD2-Fd-hA20-pdHL2

[0183] C-DDD2-Fd-hA20-pdHL2 is an expression vector for producing an a_4 construct, referred to as the tetravalent C-DDD2-Fab-hA20 hereafter, that comprises four copies of a fusion protein in which the DDD2 sequence is appended to hA20-Fab at the C-terminus of the Fd chain via a flexible peptide spacer. hA20 is a humanized monoclonal antibody specific for CD20.

[0184] The expression vector was engineered in three steps as follows. First, the expression vector hA20-IgG-pdHL2 was digested with Sac2 and NdeI to yield the 7578-bp fragment. Next, the expression vector C-DDD2-hMN-14-Fd-pdHL2 was digested with Sac2 and NdeII and the 509-bp fragment coding for CH1-DDD2 was isolated. Third, the 7578-bp fragment was ligated with the 509-bp fragment to generate C-DDD2-Fd-hA20-phHL2.

Construction of C-DDD2-Fd-hMN-3-pdHL2

[0185] C-DDD2-Fd-hMN3-pdHL2 is an expression vector for producing an a_4 construct, referred to as the tetravalent C-DDD2-Fab-hMN-3 hereafter, that comprises four copies of a fusion protein in which the DDD2 sequence is appended to hMN3-Fab at the C-terminus of the Fd chain via a flexible peptide spacer. hMN-3 is a humanized monoclonal antibody specific for the N domain of CEA (CEACAM5) or NCA-90 (CEACAM6).

[0186] The expression vector was engineered in three steps as follows. First, the expression vector hMN-3-IgG-pdHL2 was digested with Sac2 and NgoM4 to yield the 8118-bp fragment. Next, the expression vector C-DDD2-hMN-14-Fd-pdHL2 was digested with Sac2

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and NgoM4 and the 509-bp fragment coding for CH1-DDD2 was isolated. Third, the 8118-bp fragment was ligated with the 509-bp fragment to generate C-DDD2-Fd-hMN-3-phHL2.

Construction of C-DDD2-Fd-hLL2-pdHL2

[0187] C-DDD2-Fd-hLL2-pdHL2 is an expression vector for producing an a_4 construct, referred to as the tetravalent C-DDD2-Fab-hLL2 hereafter, that comprises four copies of a fusion protein in which the DDD2 sequence is appended to hLL2-Fab at the C-terminus of the Fd chain via a flexible peptide spacer. hLL2 is a humanized monoclonal antibody specific for CD22.

[0188] The expression vector was engineered in three steps as follows. First, the expression vector hLL2-IgG-pdHL2 was digested with Sac2 and NdeI to yield the 7578-bp fragment. Next, the expression vector C-DDD2-hMN-14-Fd-pdHL2 was digested with Sac2 and NdeI and the 509-bp fragment coding for CH1-DDD2 was isolated. Third, the 7578-bp fragment was ligated with the 509-bp fragment to generate C-DDD2-Fd-hLL2-phHL2.

Production, purification and characterization of the tetravalent C-DDD2-Fab-hMN-14

[0189] C-DDD2-Fd-hMN-14-pdHL2 vector was transfected into Sp/EEE myeloma cells by electroporation. The di-cistronic expression vector directs the synthesis and secretion of both hMN-14 kappa light chain and C-DDD2-Fd-hMN-14, which combine to form C-DDD2-Fab-hMN14. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 μM methotrexate (MTX).

[0190] Clones were screened for protein expression by ELISA using microtitre plates coated with WI2 (hMN-14 anti-Id) and detection was achieved with goat anti-human Fab-HRP. The highest producing clones had an initial productivity of approximately 100 mg/L, which was 10-fold higher than that of N-DDD2-Fab-hMN-14. A total of 200 mg of C-DDD2-Fab-hMN-14 was purified by protein L affinity chromatography from 1.8 liters of roller bottle culture as described above for N-DDD2-Fab-hMN-14. The SE-HPLC profile of the Protein L-purified C-DDD2-Fab-hMN-14 was similar to that of N-DDD2-Fab-hMN-14, showing four protein peaks. Two of the four protein peaks were attributed to the tetrameric a_4 (8.40 min) and dimeric a_2 (9.26 min) forms of C-DDD2-Fab-hMN-14 and the remaining two represent dimer and monomer of the *kappa* chain. The tetravalent C-DDD2-Fab-hMN-14 was separated from other molecular forms by gel filtration chromatography using a Superdex-200 column. Like N-DDD2-Fab-hMN-14, addition of TCEP converts most of the a_4 form to the a_2 form, as illustrated in Figure 21. The SE-HPLC profile of the tetravalent C-DDD2-Fab-hMN-14 on a

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tandem column system is shown in Figure 22, appearing as a single peak with a retention time of 19.57 min. The ability of the tetravalent C-DDD2-Fab-hMN-14 to bind to four WI2 fragments is shown in Figure 23.

Production, purification and characterization of the tetravalent C-DDD2-Fab-hA20

[0191] C-DDD2-Fd-hA20-pdHL2 vector was transfected into NS0 myeloma cells by electroporation. The di-cistronic expression vector directs the synthesis and secretion of both hA20 kappa light chain and C-DDD2-Fd-hA20, which combine to form C-DDD2-Fab-hA20. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 μM methotrexate (MTX).

[0192] Clones were screened for protein expression by ELISA using microtitre plates coated with WR2 (a rat anti-id to hA20) and detection was achieved with goat anti-human Fab-HRP. The highest producing clones had an initial productivity of approximately 10 mg/L. The tetravalent C-DDD2-Fab-hA20 was purified from cell culture supernatants produced in roller bottles by Protein L affinity chromatography followed by Superdex-200 gel filtration. The SE-HPLC profile of the tetravalent C-DDD2-Fab-hA20 is shown in Figure 24. The tetravalent C-DDD2-Fab-hA20 showed potent anti-proliferative activity on Daudi and Ramos even in the absence of anti-IgM (Figure 25). By contrast, the bivalent hA20 IgG or F(ab')2 was inactive in inhibiting the growth of Daudi or Ramos under the same conditions either in the absence or presence of anti-IgM. The observed anti-proliferative activity of hA20 IgG or F(ab')2 in the presence of anti-IgM was apparently due to that of anti-IgM.

Production and purification of the tetravalent C-DDD2-Fab-hMN-3

[0193] C-DDD2-Fd-hMN-3-pdHL2 vector was transfected into NS0 myeloma cells by electroporation. The di-cistronic expression vector directs the synthesis and secretion of both hMN-3 kappa light chain and C-DDD2-Fd-hMN-3, which combine to form C-DDD2-Fab-hMN-3. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 μM methotrexate (MTX).

[0194] Clones were screened for protein expression by ELISA using microtitre plates coated with CEACAM5 and detection was achieved with goat anti-human Fab-HRP. The highest producing clones had an initial productivity of approximately 10 mg/L. The tetravalent C-DDD2-Fab-hMN-3 was purified from cell culture supernatants produced in roller bottles by Protein L affinity chromatography followed by Superdex-200 gel filtration.

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Production and purification of the tetravalent C-DDD2-Fab-hLL2

[0195] C-DDD2-Fd-hLL2-pdHL2 vector was transfected into Sp2/0-derived myeloma cells by electroporation. The di-cistronic expression vector directs the synthesis and secretion of both hLL2 kappa light chain and C-DDD2-Fd-hLL2, which combine to form C-DDD2-Fab-hLL2. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 µM methotrexate (MTX).

[0196] Clones were screened for protein expression by ELISA using microtitre plates coated with WN (a rat anti-id to hLL2) and detection was achieved with goat anti-human Fab-HRP. The highest producing clones had an initial productivity of approximately 15 mg/L. The tetravalent C-DDD2-Fab-hLL2 was purified from cell culture supernatants produced in roller bottles by Protein L affinity chromatography followed by Superdex-200 gel filtration.

Example 6. Methods for generating $a_2a'_2$ constructs from two distinct a_4 and a'_4 constructs

Production, purification and characterization of the bispecific tetravalent C-DDD2-Fab-hMN-3 x C-DDD2-Fab-hA20.

[0197] The tetravalent C-DDD2-Fab-hMN-3 and the tetravalent C-DDD2-Fab-hA20 obtained from Example 5 were combined and reduced with 1 mM glutathione at RT for 1 h followed by adding oxidized glutathione to a final concentration of 2 mM. The tetrameric fraction was purified from the other molecular forms by gel filtration on a Superdex-200 column. The formation of the bispecific tetravalent C-DDD2-Fab-hMN-3 x C-DDD2-Fab-hA20 was demonstrated by ELISA using plates coated with CEACAM5 and probed with WR2, as shown in Figure 26.

Production, purification and characterization of the bispecific tetravalent C-DDD2-Fab-hMN-3 x C-DDD2-Fab-hMN-14

[0198] The tetravalent C-DDD2-Fab-hMN-3 and the tetravalent C-DDD2-Fab-hMN-14 obtained from Example 5 were combined and reduced with 1 mM glutathione at RT for 1 h followed by adding oxidized glutathione to a final concentration of 2 mM. The tetrameric fraction was purified from the other molecular forms by gel filtration on a Superdex-200 column. The formation of the bispecific tetravalent C-DDD2-Fab-hMN-3 x C-DDD2-Fab-hMN-14 was demonstrated by flow cytometry using BXPC3 cells as shown in Figure 27.

Production and purification of the bispecific tetravalent C-DDD2-Fab-hA20 x C-DDD2-Fab-hLL2

[0199] The tetravalent C-DDD2-Fab-hA20 and the tetravalent C-DDD2-Fab-hLL2 obtained from Example 5 were combined and reduced with 1 mM glutathione at RT for 1 h followed by adding oxidized glutathione to a final concentration of 2 mM. The tetrameric fraction was purified from the other molecular forms by gel filtration on a Superdex-200 column. The formation of the bispecific tetravalent C-DDD2-Fab-hA20 x C-DDD2-Fab-hLL2 was demonstrated by ELISA using plates coated with WN (a rat anti-id to hLL2) and probed with WR2 (a rat anti-id to hA20).

Table 1. Selected Examples of Type I Products for which the subunits of a_2 are based on binding domains derived from immunoglobulins

Target	Application
X	Treating or detecting a disease bearing the X marker
CD14	Treating septic shock
CD111/nectin-1	Treating herpesvirus infection
Folate receptor α	Treating filovirus infection (e.g. Ebola and Marburg viruses)
gp120	Treating HIV-1/AIDS
IL-6	Treating myeloma, arthritis and other autoimmune disease
IL-5	Treating asthma
IL-8	Treating general infection
CD154	Treating lupus, transplant rejection, AID
IgE	Treating asthma as indicated by Xolair®
LFA-1	Treating transplant rejection
CD3	Treating transplant rejection as indicated by OKT3®
β-tryptase	Treating allergy, inflammation
CD105/endoglin	Anti-angiogenesis
GpIIb/IIa	Treating thrombosis as indicated by RepPro™
TNF-α	Treating arthritis as indicated by HUMIRA™ or REMICADE®
RSV F-protein	RSV therapy as indicated by Synagis™
A1B1 of CEA	Inhibiting adhesion/invasion/metastasis of solid cancers
N domain of CEA	Inhibiting adhesion/invasion/metastasis of solid cancers
Pgp/p-170	Reversing multiple drug resistance
VEGF	Neutralizing VEGF
Placenta growth factor (PlGF)	Neutralizing
VEGFR1/Flt-1	Treating cancers
Blys/CD257	Treating lupus and arthritis
APRIL/CD256	Treating lupus and arthritis

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Table 2. Selected Examples of Type 2 Products for which the subunits of a_2 are based on nonimmunoglobulin proteins

Precursor	Application
Soluble Tumor necrosis factor receptor (sTNFR)	Treating arthritis as indicated by Enbrel®
sTNFR-VL-CL	Treating arthritis as indicated by Enbrel®
sTNFR-CH2-CH3	Treating arthritis as indicated by Enbrel®
Ranpirnase (Rap)	Treating cancers
Rap-VL-CL	Treating cancers
Rap-CH2-CH3	Treating cancers
Tissue plasminogen activator (tPA)	Treating diseases as indicated by Activase®
tPA-VL-CL	Treating diseases as indicated by Activase®
tPA-CH2-CH3	Treating diseases as indicated by Activase®
Erythropoietin (EPO)	Treating anemia as indicated by Epogen®
EPO-VL-CL	Treating anemia as indicated by Epogen®
EPO-CH2-CH3	Treating anemia as indicated by Epogen®
Thrombopoietin (TPO)	Treating thrombocytopenia
TPO-VL-CL	Treating thrombocytopenia
TPO-CH2-CH3	Treating thrombocytopenia
Interlukin (IL)-11	Treating thrombocytopenia as indicated by Neumega®
IL-11-VL-CL	Treating thrombocytopenia as indicated by Neumega®
IL-11-CH2-CH3	Treating thrombocytopenia as indicated by Neumega®
Granulocyte-colony stimulating factor (G-CSF)	Treating neutropenia as indicated by Neupogen®
G-CSF-VL-CL	Treating neutropenia as indicated by Neupogen®
G-CSF-CH2-CH3	Treating neutropenia as indicated by Neupogen®
Interferon (IFN)-α2	Treating hepatitis as indicated by Intron A®
IFN-α2-VL-CL	Treating hepatitis as indicated by Intron A®
IFN-α2-CH2-CH3	Treating hepatitis as indicated by Intron A®
IFN-β1	Treating multiple sclerosis as indicated by Betaseron®
IFN-β1-VL-CL	Treating multiple sclerosis as indicated by Betaseron®
IFN-β1-CH2-CH3	Treating multiple sclerosis as indicated by Betaseron®
Coagulation factor IX	Treating hemophilia B as indicated by BeneFix™
Coagulation factor IX-VL-CL	Treating hemophilia B as indicated by BeneFix™
Coagulation factor-IX-CH2-CH3	Treating hemophilia B as indicated by BeneFix™
GM-CSF	Treating diseases as indicated by Leukine®

Precursor	Application
GM-CSF-VL-CL	Treating diseases as indicated by Leukine®
GM-CSF-CH2-CH3	Treating diseases as indicated by Leukine®
PlGF antagonist peptides	Neutralizing
VEGF antagonist peptides	Neutralizing VEGF
Tyrosine kinase inhibitors	Treating cancers
Aβ12-28P fused to CH2-CH3	Treating Alzheimer's disease

Table 3. Selected Examples of Type 3 Products for which the subunits of a_4 are based on binding domains derived from immunoglobulins

Target	Application
X	Treating or detecting a disease bearing the X marker
CD14	Treating septic shock
CD111/nectin-1	Treating herpes simplex virus infection
Folate receptor α	Treating filovirus infection (e.g. Ebola and Marburg viruses)
gp120	Treating HIV-1/AIDS
IL-6	Treating myeloma, arthritis and other autoimmune disease
IL-5	Treating asthma
IL-8	Treating general infection
CD154	Treating lupus, transplant rejection, AID
IgE	Treating asthma as indicated by Xolair®
LFA-1	Treating transplant rejection
β-tryptase	Treating allergy, inflammation
CD105/endoglin	Anti-angiogenesis
GpIIb/IIa	Treating thrombosis as indicated by RepPro™
TNF-α	Treating arthritis as indicated by HUMIRA™ or REMICADE®
RSV F-protein	RSV therapy as indicated by Synagis™
A1B1 of CEA	Inhibiting adhesion/invasion/metastasis of solid cancers
N domain of CEA	Inhibiting adhesion/invasion/metastasis of solid cancers
CD20	Treating B-cell lymphomas or autoimmune diseases, as indicated by Rituxan™
CD22	Treating B-cell lymphomas or autoimmune diseases
CD19	Treating B-cell lymphoma or autoimmune diseases
CD80	Lymphoma therapy
HLA-DR	Treating cancers or autoimmune diseases
CD74	Treating cancers or autoimmune diseases
MUC1	Treating cancers
HER2/neu	Treating cancers
EGFR	Treating cancers
Insulin-like growth factor	Treating cancers
MIF	Treating autoimmune diseases
CD83	Treating autoimmune diseases
CD3	Treating transplant rejection as indicated by OKT3®
IL-2Rα/CD25	Preventing kidney transplant rejection as indicated by Zenapax® or Simulect®
ICAM-1	Preventing human rhinovirus infection
Pgp/p-170	Reversing multiple drug resistance

Target	Application
VEGF	Neutralizing VEGF
PlGF	Neutralizing
VEGFR1/Flt-1	Treating cancers
Blys/CD257	Treating lupus and arthritis
April/CD256	Treating lupus and arthritis

Table 4. Selected Examples of Type 4 Products for which the subunits of a₄ are based on nonimmunoglobulin proteins

Precursor	Application
sTNFR	Treating arthritis as indicated by Enbrel®
sTNFR-VL-CL	Treating arthritis as indicated by Enbrel®
sTNFR-CH2-CH3	Treating arthritis as indicated by Enbrel®
Rap	Treating cancers
Rap-VL-CL	Treating cancers
Rap-CH2-CH3	Treating cancers
tPA	Treating diseases as indicated by Activase®
tPA-VL-CL	Treating diseases as indicated by Activase®
tPA-CH2-CH3	Treating diseases as indicated by Activase®
EPO	Treating anemia as indicated by Epogen® or Aranesp®
EPO-VL-CL	Treating anemia as indicated by Epogen® or Aranesp®
EPO-CH2-CH3	Treating anemia as indicated by Epogen® or Aransesp®
TPO	Treating thrombocytopenia
TPO-VL-CL	Treating thrombocytopenia
TPO-CH2-CH3	Treating thrombocytopenia
IL-11	Treating thrombocytopenia as indicated by Neumega®
IL-11-VL-CL	Treating thrombocytopenia as indicated by Neumega®
IL-11-CH2-CH3	Treating thrombocytopenia as indicated by Neumega®
G-CSF	Treating neutropenia as indicated by Neupogen®
G-CSF-VL-CL	Treating neutropenia as indicated by Neupogen®
G-CSF-CH2-CH3	Treating neutropenia as indicated by Neupogen®
IFN-α2	Treating hepatitis as indicated by Intron A®
IFN-α2-VL-CL	Treating hepatitis as indicated by Intron A®
IFN-α2-CH2-CH3	Treating hepatitis as indicated by Intron A®
IFN-β1	Treating multiple sclerosis as indicated by Betaseron®
IFN-β1-VL-CL	Treating multiple sclerosis as indicated by Betaseron®
IFN-β1-CH2-CH3	Treating multiple sclerosis as indicated by Betaseron®
Coagulation factor IX	Treating hemophilia B as indicated by BeneFix™
Coagulation factor IX-VL-CL	Treating hemophilia B as indicated by BeneFix™
Coagulation factor-IX-CH2-CH3	Treating hemophilia B as indicated by BeneFix™
GM-CSF	Treating diseases as indicated by Leukine®
GM-CSF-VL-CL	Treating diseases as indicated by Leukine®
GM-CSF-CH2-CH3	Treating diseases as indicated by Leukine®
PlGF antagonist peptides	Neutralizing PlGF or Flt-1, also treating cancers
VEGF antagonist peptides	Neutralizing VEGF, also treating cancers
Tyrosine kinase inhibitors	Treating cancers
Aβ12-28P fused to CH2-CH3	Treating Alzheimer's disease

Table 5. Selected Examples of Type 5 products for which the subunits of $a_2a'_2$ are based on binding domains of two different immunoglobulins

Target 1	Target 2	Application
CD20	CD22	Treating lymphomas or autoimmune diseases
CD19	CD20	Treating lymphomas or autoimmune diseases
EGFR	IGFR1	Treating solid tumors
VEGFR1/Flt-1	VEGFR2/KDR	Blocking VEGF binding
VEGFR3/Flt-4	VEGFR2/KDR	Blocking VEGF binding
CD19	CD3/TCR	Treating cancers
CD19	CD16/FcγRIIIa	Treating cancers
CD19	CD64/FcγRI	Treating cancers
HER2/neu	CD89/FcαRI	Treating cancers
HER2/neu	CD16	Treating cancers
HER2/neu	CD64	Treating cancers
HER2/neu	CD3	Treating cancers
HER2 (Herceptin)	HER2 (Omnitarg)	Treating cancers
HER2	HER3	Treating cancers
CD30	CD64	Treating cancers
CD33	CD64	Treating cancers
EGFR	CD2	Treating cancers
EGFR	CD64	Treating cancers
EGFR	CD16	Treating cancers
EGFR	CD89	Treating cancers
PfMSP-1	CD3	Treating malaria
EpCAM/17-1A	CD3	Treating cancers
hTR	CD3	Treating cancers
IL-2R/Tac	CD3	Treating cancers
CA19-9	CD16	Treating cancers
MUC1	CD64	Treating cancers
HLA class II	CD64	Treating cancers
G_{D2}	CD64	Treating neuroblastoma
Carbonic anhydrase IX	CD89	Treating renal cell carcinoma
TAG-72	CD89	Treating cancers
EpCAM	Adenovirus fiber knob	Retargeting viral vector to EpCAM+ cancers
PSMA	Adenovirus fiber knob	Retargeting viral vector to prostate cancers
CEA	Adenovirus fiber knob	Retargeting viral vector to CEA-positive cancer
HMWMAA	Adenovirus fiber knob	Retargeting viral vector to melanoma
Carbonic anhydrase IX	Adenovirus fiber knob	Retargeting viral vector to renal cell carcinoma
CD40	Adenovirus fiber knob	Retargeting viral vector to dendritic cells
M13 coat protein	Alkaline phosphatase	Detecting virus
GpIIb/IIIa	tPA	Enhancing thrombolysis
A1B1 of CEA	N of CEA	Inhibiting cancer invasion/metastasis
CD20	CD55	Treating B-cell lymphoma
CD20	CD59	Treating B-cell lymphoma
CD20	CD46	Treating B-cell lymphoma
Carbonic anhydrase IX	CD55	Treating renal cell carcinoma
EpCAM	CD55	Treating cancers

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Table 5 (Continued). Selected Examples of Type 5 products for which the subunits of
a₂a'₂ are based on binding domains of two different immunoglobulins

Target 1	Target 2	Application
Migration inhibitory factor (MIF)	Lipopolysaccharide (LPS)	Treating sepsis and septic shock
MIF	C5a receptor (C5aR)	Treating sepsis and septic shock
MIF	IL-6	Treating sepsis and septic shock
Toll-like receptor-2 (TLR2)	LPS	Treating sepsis and septic shock
High mobility group box protein 1 (HMGB-1)	TNF-α	Treating sepsis and septic shock
MIF	NCA-90/CEACAM6	Treating cancer, sepsis and septic shock
MIF	HLA-DR	Treating sepsis and septic shock
MIF	Low-density lipoprotein (LDL)	Treating atherosclerosis
NCA90	LDL	Treating atherosclerosis
CD83	LDL	Treating atherosclerosis
CD74	LDL	Treating atherosclerosis
TNF	CD20	Lymphoma therapy
TNF	CD22	Lymphoma therapy
TNF	CD74	Treating cancers
TNF	MIF	Treating autoimmune diseases
TNF	CD83	Treating autoimmune diseases
Tumor antigens	Histamine-succinly-glycine (HSG)	Pre-targeting applications for cancer diagnosis and therapy
Blys/CD257	April/CD256	Treating lupus and arthritis

Table 6. Selected Examples of Type 6 products for which the subunits of a₂a'₂ are based
on immunoglobulins and non-immunoglobulins

Target for mAb	Precursor for nonimmunoglobulin	Application
CD74	Rap-VL-CL	Treating cancers
CD22	Rap-VL-CL	Treating cancers
MUC1	Rap-VL-CL	Treating cancers
EGP-1	Rap-VL-CL	Treating cancers
IGF1R	Rap –VL-CL	Treating cancers
Pgp/p-170	Rap-VL-CL	Treating cancers
CD22	Pseudomonas exotoxin (PE)38	Treating cancers
CD30	PE38	Treating cancers
CD25/Tac	PE38	Treating cancers
Le^{Y}	PE38	Treating cancers
Mesothelin	PE38	Treating cancers
HER2	PE38	Treating cancers
EpCAM	PE38	Treating cancers
Pgp/p-170	PE38	Treating cancers
CD25	dgA	Treating cancers
CD30	dgA	Treating cancers

Target for mAb	Precursor for nonimmunoglobulin	Application
CD19	dgA	Treating cancers
CD22	dgA	Treating cancers
CD25	PLC	Treating cancers
Gp240	Gelonin	Treating melanoma
Pgp/p-170	IL-2	Treating cancers
CD3	DT390	Treating graft versus host disease (GVHD)
GpIIb/IIIa	tPA	Enhancing thrombolysis
GpIIb/IIIa	urokinase	Enhancing thrombolysis
GpIIb/IIIa	hirudin	Enhancing thrombolysis
X	Carboxypeptidase G2 (CPG2)	Prodrug therapy
X	penicillinamidase	Prodrug therapy
X	β-lactamase	Prodrug therapy
X	Cytosine deaminase	Prodrug therapy
X	Nitroreductase	Prodrug therapy
Aβ	Tf	Treating Alzheimer's disease

Table 7. Selected Examples of Type 7 products for which the subunits of $a_2a'_2$ are based on two different non-immunoglobulins

Precursor 1	Precursor 2	Application
IL-4	PE38	Treating pancreatic cancer
IL-4	Rap-VL-CL	Treating pancreatic cancer
sIL-4R	sIL-13R	Treating asthma, allergy
Aβ12-28P fused to CH2-CH3	Tf	. Treating Alzheimer's disease
Aβ12-28P	Tf	Treating Alzheimer's disease

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CLAIMS

WHAT IS CLAIMED IS:

1.   A composition comprising a homodimer, each monomer of the homodimer comprising a dimerization and docking domain (DDD) attached to a precursor.

2.   The composition of claim 1, wherein the DDD comprises the sequence of SEQ ID NO:1 (DDD1) or SEQ ID NO:2 (DDD2).

3.   The composition of claim 1, wherein the monomer is a fusion protein comprising the precursor and the DDD.

4.   The composition of claim 1, wherein the precursor is chemically linked to the DDD.

5.   The composition of claim 3, further comprising a linker peptide between the precursor and the DDD.

6.   The composition of claim 1, wherein the precursor comprises a protein, peptide, peptide mimetic, polynucleotide, RNA*i*, oligosaccharide, avimer, aptamer, antibody, antibody fragment, natural or synthetic polymeric substance, nanoparticle, quantum dot, organic compound or inorganic compound.

7.   The composition of claim 3, wherein the precursor is an Fd fragment of an antibody.

8.   The composition of claim 7, further comprising the light chain of the antibody.

9.   The composition of claim 8, wherein the light chain binds to the Fd fragment to form an Fab fragment.

10.   The composition of claim 6, wherein the antibody or fragment thereof is a humanized antibody, human antibody or chimeric antibody.

11.   The composition of claim 9, wherein the Fab fragment is selected from the group consisting of the Fab fragments of hMN-14, L19, hA20, hLL2, L243, hCC49, 7E3, hLL1, hPAM4, hRS7, rH1, L49, anti-CD14, anti-CD111, Humira®, REMICADE®, Xolair®, Synagis® and hMN-15.

12.   The composition of claim 6, wherein the precursor comprises a protein selected from the group consisting of a bacterial toxin, a plant toxin, ricin, abrin, a

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ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtherin toxin, Pseudomonas exotoxin, Pseudomonas endotoxin, Ranpirnase (Rap), Rap (N69Q), PE38, dgA, DT390, PLC, tPA, a cytokine, a growth factor, a soluble receptor component, surfactant protein D, IL-4, sIL-4R, sIL-13R,

5   VEGF$_{121}$, TPO, EPO, a clot-dissolving agent, an enzyme, a fluorescent protein, sTNFα-R, an avimer, a scFv, a dsFv and a nanobody.

13.   The composition of claim 6, wherein the precursor comprises a polypeptide fused to an immunoglobulin light chain (VL-CL) or an immunoglobulin Fc domain (CH2-CH3).

10   14.   The composition of claim 13, wherein the cysteine at the carboxyl-terminus of the CL that connects the CL to CH1 is deleted or mutated to a non-cysteine.

15.   The composition of claim 13, wherein the immunoglobulin light chain or the Fc domain is selected from a human or humanized antibody.

16.   The composition of claim 1, wherein the DDD sequence is derived from

15   the regulatory subunits of cAMP-dependent protein kinase (PKA).

17.   The composition of claim 6, wherein the precursor has at least one binding site for carbonic anhydrase IX, alpha-fetoprotein, A3, antigen specific for A33 antibody, Ba 733, BrE3-antigen, CA125, CD1, CD1a, CD3, CD5, CD15, CD16, CD19, CD20, CD21, CD22, CD23, CD25, CD30, CD33, CD38, CD45, CD74, CD79a, CD80, CD138,

20   colon-specific antigen-p (CSAp), CEA (CEACAM5), CEACAM6, CSAp, EGFR, EGP-1, EGP-2, Ep-CAM, Flt-1, Flt-3, folate receptor, HLA-DR, human chorionic gonadotropin (HCG) and its subunits, HER2/neu, hypoxia inducible factor (HIF-1), Ia, IL-2, IL-6, IL-8, insulin growth factor-1 (IGF-1), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, macrophage inhibition factor (MIF), MAGE, MUC1, MUC2, MUC3, MUC4, NCA66, NCA95,

25   NCA90, antigen specific for PAM-4 antibody, placental growth factor, p53, prostatic acid phosphatase, PSA, PSMA, RS5, S100, TAC, TAG-72, tenascin, TRAIL receptors, Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGF, ED-B fibronectin, 17-1A-antigen, an angiogenesis marker, an oncogene marker or an oncogene product.

30   18.   The composition of claim 1, further comprising one or more effectors or carriers conjugated to the homodimer by either covalent or non-covalent linkage.

19.   The composition of claim 18, wherein the effector is a diagnostic agent, a therapeutic agent, a chemotherapeutic agent, a radioisotope, an imaging agent, an anti-angiogenic agent, a cytokine, a chemokine, a growth factor, a drug, a prodrug, an enzyme, a binding molecule, a ligand for a cell surface receptor, a chelator, an immunomodulator, 5   an oligonucleotide, a hormone, a photodetectable label, a dye, a peptide, a toxin, a contrast agent, a paramagnetic label, an ultrasound label, a pro-apoptotic agent, a liposome, a nanoparticle or a combination thereof.

20.   The composition of claim 19, wherein the anti-angiogenic agent is angiostatin, baculostatin, canstatin, maspin, anti-VEGF antibodies or peptides, anti-10   placental growth factor antibodies or peptides, anti-Flk-1 antibodies, anti-Flt-1 antibodies or peptides, laminin peptides, fibronectin peptides, plasminogen activator inhibitors, tissue metalloproteinase inhibitors, interferons, interleukin 12, IP-10, Gro-ß, thrombospondin, 2-methoxyoestradiol, proliferin-related protein, carboxiamidotriazole, CM101, Marimastat, pentosan polysulphate, angiopoietin 2 , interferon-alpha, herbimycin 15   A, PNU145156E, 16K prolactin fragment, Linomide, thalidomide, pentoxifylline, genistein, TNP-470, endostatin, paclitaxel, accutin, angiostatin, cidofovir, vincristine, bleomycin, AGM-1470, platelet factor 4 or minocycline.

21.   The composition of claim 19, wherein the therapeutic agent is abrin, amantadine, amoxicillin, amphotericin B, ampicillin, aplidin, azaribine, anastrozole, 20   azacytidine, aztreonam, azithromycin, bacitracin, bactrim, Batrafen®, bifonazole, bleomycin, bortezomib, bryostatin-1, busulfan, calicheamycin, camptothecin, 10-hydroxycamptothecin, carbenicillin, caspofungin, carmustine, cefaclor, cefazolin, cephalosporins, cefepime, ceftriaxone, cefotaxime, celebrex, chlorambucil, chloramphenicol, Cipro®, cisplatin, irinotecan (CPT-11), SN-38, carboplatin, cladribine, 25   cyclophosphamide, cytarabine, dacarbazine, docetaxel, dactinomycin, daunomycin glucuronide, daunorubicin, dexamethasone, diethylstilbestrol, diphtheria toxin, DNase I, doxorubicin, 2-pyrrolinodoxorubicine (2P-DOX), doxycycline, cyano-morpholino doxorubicin, doxorubicin glucuronide, epirubicin glucuronide, ethinyl estradiol, estramustine, estrogen receptor binding agents, etoposide, etoposide glucuronide, 30   etoposide phosphate, erythrocycline, erythromycin, flagyl, farnesyl-protein transferase inhibitors, floxuridine (FUdR), 3',5'-O-dioleoyl-FudR (FUdR-dO), fludarabine, flutamide, fluorouracil, fluoxymesterone, ganciclovir, gentamycin, gelonin, gemcitabine, hydroxyprogesterone caproate, hydroxyurea, idarubicin, ifosfamide, , isoniazid,

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itraconazole, kanamycin, ketoconazole, L-asparaginase, leucovorin, lomustine,

mechlorethamine, medroprogesterone acetate, megestrol acetate, melphalan,

mercaptopurine, 6-mercaptopurine, methotrexate, mitoxantrone, mithramycin,

mitomycin, mitotane, minocycline, naftifine, nalidixic acid, neomycin, navelbine,

5   nitrosurea, nystatin, onconase, oxacillin, paromomycin, penicillin, pentamidine,

piperacillin-tazobactam, phenyl butyrate, prednisone, procarbazine, paclitaxel,

pentostatin, pokeweed antiviral protein, PSI-341, Pseudomonas exotoxin, Pseudomonas

endotoxin, raloxifene, rapLR1, ribonuclease, ricin, semustine, rifabutin, rifampin,

rimantadine, streptomycin, sulfamethoxazole, sulfasalazine, Staphylococcal enterotoxin-

10   A, streptozocin, tamoxifen, taxanes, taxol, testosterone propionate, tetracycline,

thalidomide, thioguanine, thiotepa, teniposide, topotecan, transplatinum, trimethoprim

sulfamethoxazole, uracil mustard, valacyclovir, vancomycin, velcade, vinblastine,

vinorelbine, vincristine, zanamir, zithromycin, an antisense oligonucleotide, an

interference RNA, or a combination thereof.

15   22.   The composition of claim 19, wherein the diagnostic or therapeutic agent

is selected from the group consisting of ^{225}Ac, ^{211}At, ^{212}Bi, ^{213}Bi, ^{14}C, ^{51}Cr, ^{36}Cl, ^{45}Ti,

^{57}Co, ^{58}Co, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{166}Dy, ^{152}Eu, ^{18}F, ^{67}Ga, ^{68}Ga, ^{195m}Hg, ^{166}Ho, ^{3}H, ^{111}In, ^{123}I,

^{124}I, ^{125}I, ^{131}I, ^{52}Fe, ^{59}Fe ^{177}Lu, ^{191}Os, ^{212}Pb, ^{32}P, ^{33}P, ^{142}Pr, ^{195m}Pt, ^{223}Ra, ^{186}Re, ^{188}Re, ^{189}Re,

^{47}Sc, ^{75}Se ^{111}Ag, ^{153}Sm, ^{89}Sr, ^{35}S, ^{161}Tb, ^{94m}Tc, ^{99m}Tc, ^{86}Y, ^{90}Y, and ^{89}Zr.

20   23.   The composition of claim 19, wherein the imaging agent is selected from

the group consisting of chromium (III), manganese (II), iron (III), iron (II), cobalt (II),

nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III),

vanadium (II), terbium (III), dysprosium (III), holmium (III) erbium (III), lanthanum (III),

gold (III), lead (II) and bismuth (III).

25   24.   The composition of claim 19, wherein the photodetectable label is selected

from the group consisting of Alexa 350, Alexa 430, AMCA, aminoacridine, BODIPY

630/650, BODIPY 650/665, BODIPY-FL, BODIPY-R6G, BODIPY-TMR, BODIPY-

TRX,   5-carboxy-4',   5'-dichloro-2',7'-dimethoxy   fluorescein,   5-carboxy-2',4',5',7'-

tetrachlorofluorescein, 5-carboxyfluorescein, 5-carboxyrhodamine, 6-carboxyrhodamine,

30   6-carboxytetramethyl amino, Cascade Blue, Cy2, Cy3, Cy5,6-FAM, dansyl chloride,

Fluorescein, HEX, 6-JOE, NBD (7-nitrobenz-2-oxa-1,3-diazole), Oregon Green 488,

Oregon Green 500, Oregon Green 514, Pacific Blue, phthalic acid, terephthalic acid,

isophthalic acid, cresyl fast violet, cresyl blue violet, brilliant cresyl blue, para-

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aminobenzoic acid, erythrosine, phthalocyanines, azomethines, cyanines, xanthines, succinylfluoresceins, rare earth metal cryptates, europium trisbipyridine diamine, a europium cryptate or chelate, diamine, dicyanins, La Jolla blue dye, allopycocyanin, allococyanin B, phycocyanin C, phycocyanin R, thiamine, phycoerythrocyanin, phycoerythrin R, REG, Rhodamine Green, rhodamine isothiocyanate, Rhodamine Red, ROX, TAMRA, TET, TRIT (tetramethyl rhodamine isothiol), Tetramethylrhodamine, and Texas Red.

25.   The composition of claim 18, wherein the effectors or carriers are chemically cross-linked to the homodimer.

26.   The composition of claim 18, wherein the homodimer is attached to two or more effectors or two or more carriers.

27.   The composition of claim 26, wherein the two or more carriers or two or more effectors are either identical or different.

28.   The composition of claim 18, wherein the one or more carriers comprise at least one diagnostic or therapeutic agent.

29.   A composition comprising two homodimers according to claim 1, wherein two homodimers are covalently bound to form a tetramer.

30.   The composition of claim 29, wherein the DDD comprises the sequence of SEQ ID NO:2 (DDD2).

31.   The composition of claim 30, wherein the two homodimers are covalently bound by disulfide bonds between the DDD2 sequences.

32.   The composition of claim 30, wherein the two homodimers in the tetramer are identical.

33.   The composition of claim 30, wherein the two homodimers in the tetramer are different.

34.   The composition of claim 29, wherein the first homodimer comprises a first monomer that comprises a DDD sequence linked to a first precursor and the second homodimer comprises a second monomer that comprises a DDD sequence linked to a second precursor.

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35.   The composition of claim 34, wherein the two homodimers are held together by disulfide bonds between the DDD moieties of each of the homodimers.

36.   The composition of claim 34, wherein the first precursor and second precursor have binding affinities for target molecules, composites, aggregates, cells, antigens or tissues.

37.   The composition of claim 36, wherein the first and second precursors have affinities for the same target molecules, composites, aggregates, cells, antigens or tissues.

38.   The composition of claim 36, wherein the first and second precursors have affinities for two different target molecules, composites, aggregates, cells, antigens or tissues.

39.   The composition of claim 34, wherein the first precursor has a binding site for a target molecule, composite, aggregate, cell, antigen or tissue and the second precursor has a binding site for a hapten.

40.   The composition of claim 34, wherein the first precursor has a binding affinity for a cell surface receptor, alkaline phosphatase, horseradish peroxidase, β-galactosidase, tpA, streptokinase, hirudin, urokinase, CA19-9, CEA, CEACAM6, CD19, CD20, CD22, CD30, CD33, CD40, CD74, ED-B fibronectin, EGFR, G_{D2}, G250-antigen, HER2/neu, hTR, HLA class II, HMWMAA, HN/NDV, IGF1R, IL-2R/Tac, IL-17, MUC1, PSMA, M13 coat protein, GpIIb/IIIa, CD74, EGP-1, CD25/Tac, Le^Y, mesothelin, Erb-B2, Erb-B3, EpCAM, GP240, GPIIb/IIIa, p97, CD3, IL-4R, IL-4, IL-13, VEGFR-2, CD14, CD111/nectin-1, folate receptor α, gp120, IL-6, Il-5, IL-8, CD154, IgE, LFA-1, β-tryptase, CD105/endoglin, TNFα, RSV F-protein, A1B1 of CEA, N domain of CEA, PfMSP-1, TAG-72, MUC1, MUC2, MUC3, MUC4, VEFGR1/Flt-1, VEGFR2/KDR or VEGRF3/Flt-4.

41.   The composition of claim 34, wherein the second precursor has a binding affinity for IL-17, histamine-succinyl-glycine (HSG), indium-DTPA, CD22, CD20, EGFR, IGF1R, VEFGR1/Flt-1, VEGFR2/KDR, VEGRF3/Flt-4, CD3, CD16, CD64, CD89, CD2, adenovirus fiber knob, M13 coat protein, GpIIb/IIIa, alkaline phosphatase, horseradish peroxidase, β-galactosidase, tpA, streptokinase, hirudin or urokinase.

42.   The composition of claim 34, wherein the first precursor has an affinity for a cell surface antigen selected from the group consisting of CEA, ED-B fibronectin,

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CD20, CD22, CD19, EGFR, IGF1R, VEFGR1/Flt-1, VEGFR2/KDR, VEGRF3/Flt-4,

HER2/neu, CD30, CD33, PfMSP-1, HN/NDV, EpCAM/17-1A, hTR, IL-2R/Tac, CA19-

9, MUC1, HLA class II, $G_{D2,}$ G250, TAG-72, PSMA, CEACAM6, HMWMAA, CD40,

M13 coat protein, and GPIIb/IIIa, and wherein the second precursor has an affinity either

5   for a hapten selected from the group consisting of histamine-succinyl-glycine (HSG) and

indium-DTPA, or for a cell surface antigen selected from the group consisting of CD22,

CD20, EGFR, IGF1R, VEFGR1/Flt-1, VEGFR2/KDR, VEGRF3/Flt-4, CD3, CD16,

CD64, CD89, CD2, and adenovirus fiber knob.

        43.   The composition of claim 34, wherein the first precursor has an affinity

10   either for a cell surface antigen selected from the group consisting of M13 coat protein

and GpIIb/IIIa, or for a biomolecule selected from the group consisting of alkaline

phosphatase, horseradish peroxidase, β-galactosidase, tpA, streptokinase, hirudin, and

urokinase, and wherein the second precursor has an affinity either for a cell surface

antigen selected from the group consisting of M13 coat protein and GpIIb/IIIa, or for a

15   biomolecule selected from the group consisting of alkaline phosphatase, horseradish

peroxidase, β-galactosidase, tpA, streptokinase, hirudin, and urokinase,

        44.   The composition of claim 34, wherein the first precursor has an affinity for

a cell surface antigen selected from the group consisting of CD3, CD74, CD19, CD22,

MUC1, EGP-1, IGF1R CD30, CD25/Tac, LeY, mesothelin, Erb-B2, EpCAM, GP240,

20   GPIIb/IIIa, and p97, and wherein the second precursor is selected from the group

consisting of a ribonuclease, Ranpirnase, a bacterial toxin, a plant toxin, PE38, dgA,

DT390, phospholipase C (PLC), gelonin, a clot-dissolving protein, tPA, urokinase and

hirudin.

        45.   The composition of claim 34, wherein the first precursor has an affinity for

25   any cell surface antigen associated with a disease or a medical condition and the second

precursor is selected from the group consisting of a cytokine, a growth factor,

carboxypeptidase G2, penicilliamidase, β-lactamase, cytosine deaminase, nitroreductase,

β-galactosidase, green fluorescence protein (GFP) or its various engineered analogs,

alkaline phosphatase, horseradish peroxidase, and streptavidin.

30   46.   The composition of claim 34, wherein the first precursor is selected from

the group consisting of a ribonuclease, a bacterial toxin, a plant toxin, a cytokine, a

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growth factor and surfactant protein D (Sp-D), and the second precursor has an affinity for any cell surface antigen associated with a disease or a medical condition.

47.   The composition of claim 34, wherein the first precursor and the second precursor are selected from the group consisting of a ligand for a cell surface receptor, IL-4, $VEGF_{121}$, a soluble receptor component, sIL-4R, sIL-13R, a toxin, PE38, shiga-like toxin and diphtheria toxin.

48.   The composition of claim 34, wherein the first and the second precursors are the same and are selected from the group consisting a binding molecule for CD14, CD11/nectin-1, folate receptor α, gp120, IL-6, IL-5, IL-8, CD154, IgE, LFA-1, β-tryptase, CD105/endoglin, GpIIb/IIIa, TNFα, RSV F-protein, A1B1 of CEA, and N-domain of CEA.

49.   The composition of claim 34, wherein the first and the second precursors are the same and are selected from the group consisting a cytokine, a growth factor, a soluble receptor component, tPA, TPO, EPO, and sTNFα-R.

50.   A method comprising:
    a)   obtaining a homodimer according to claim 1; and
    b)   administering the homodimer to a subject with a condition;
    wherein the homodimer has a therapeutic effect on the condition.

51.   The method of claim 50, wherein the condition is cancer, hyperplasia, diabetic retinopathy, juvenile diabetes, macular degeneration, inflammatory bowel disease, Crohn's disease, ulcerative colitis, rheumatoid arthritis, sarcoidosis, asthma, edema, pulmonary hypertension, psoriasis, corneal graft rejection, neovascular glaucoma, Osler-Webber Syndrome, myocardial angiogenesis, plaque neovascularization, restenosis, neointima formation after vascular trauma, telangiectasia, hemophiliac joints, angiofibroma, fibrosis associated with chronic inflammation, lung fibrosis, deep venous thrombosis or wound granulation.

52.   The method of claim 51, wherein the condition is cancer and the precursor has a binding affinity for a tumor-associated antigen selected from the group consisting of carbonic anhydrase IX, alpha- fetoprotein, A3, antigen specific for A33 antibody, Ba 733, BrE3-antigen, CA125, CD1, CD1a, CD3, CD5, CD15, CD16, CD19, CD20, CD21, CD22, CD23, CD25, CD30, CD33, CD38, CD45, CD74, CD79a, CD80, CD138, colon-

specific antigen-p (CSAp), CEA (CEACAM5), CEACAM6, EGFR, EGP-1, EGP-2, Ep-CAM, Flt-1, Flt-3, folate receptor, G250 antigen, HLA-DR, human chorionic gonadotropin (HCG) and its subunits, HER2/neu, hypoxia inducible factor (HIF-1), Ia, IL-2, IL-6, IL-8, insulin growth factor-1 (IGF-1), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, macrophage inhibition factor (MIF), MAGE, MUC1, MUC2, MUC3, MUC4, NCA66, NCA95, NCA90, antigen specific for PAM-4 antibody, placental growth factor, p53, prostatic acid phosphatase, PSA, PSMA, RS5, S100, TAC, TAG-72, tenascin, TRAIL receptors, Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGF, ED-B fibronectin, 17-1A-antigen, an angiogenesis marker, an oncogene marker and an oncogene product.

53.   The method of claim 52, wherein the cancer is acute lymphoblastic leukemia, acute myelogenous leukemia, renal cell carcinoma, biliary cancer, brain cancers, breast cancer, cervical cancer, chronic lymphocytic leukemia, chronic myelogenous leukemia, multiple myeloma, colorectal cancer, endometrial cancer, esophageal cancer, gastric cancer, head and neck cancer, Hodgkin's lymphoma, lung cancer, medullary thyroid cancer, non-Hodgkin's lymphoma, ovarian cancer, testicular cancer, pancreatic cancer, glioma, liver cancer, prostate cancer, melanoma or urinary bladder cancer.

54.   The method of claim 53, further comprising administering one or more anti-cancer therapies in combination with the homodimer.

55.   The method of claim 54, wherein the therapy comprises administering a chemotherapeutic agent, a cytokine, radiation therapy, immunotherapy, radioimmunotherapy, localized hyperthermia, laser irradiation, an anti-angiogenic agent or surgical excision.

56.   A method comprising:

a)   obtaining a tetramer according to claim 34; and

b)   administering the tetramer to a subject with a condition;

wherein the tetramer has a therapeutic effect on the condition.

57.   The method of claim 56, further comprising administering to the subject a hapten that binds to the second precursor.

58.   The method of claim 57, wherein the hapten is administered after the tetramer has localized to a tissue associated with the condition.

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59.   The method of claim 58, wherein the hapten is attached to an agent selected from the group consisting of an anti-angiogenic agent, a chemotherapeutic agent, a cytokine, a drug, a prodrug, a toxin, an enzyme, an oligonucleotide, a radioisotope, an immunomodulator, an antibiotic, an anti-viral agent, an anti-fungal agent, a hormone, a

5   binding molecule, a lipid, a polymer, a micelle, a liposome, a nanoparticle or a combination thereof.

60.   The method of claim 59, wherein the condition is caused by a fungus.

61.   The method of claim 60, wherein the fungus is *Microsporum, Trichophyton, Epidermophyton, Sporothrix schenckii, Cryptococcus neoformans,*

10   *Coccidioides immitis, Histoplasma capsulatum, Blastomyces dermatitidis* or *Candida albican.*

62.   The method of claim 59, wherein the condition is caused by a virus.

63.   The method of claim 62, wherein the virus is human immunodeficiency virus (HIV), herpes virus, cytomegalovirus, rabies virus, influenza virus, human

15   papilloma virus, hepatitis B virus, hepatitis C virus, Sendai virus, feline leukemia virus, Reo virus, polio virus, human serum parvo-like virus, simian virus 40, respiratory syncytial virus, mouse mammary tumor virus, Varicella-Zoster virus, Dengue virus, rubella virus, measles virus, adenovirus, human T-cell leukemia viruses, Epstein-Barr virus, murine leukemia virus, mumps virus, vesicular stomatitis virus, Sindbis virus,

20   lymphocytic choriomeningitis virus or blue tongue virus.

64.   The method of claim 59, wherein the condition is caused by a bacterium.

65.   The method of claim 64, wherein the bacterium is *Bacillus anthracis, Streptococcus agalactiae, Legionella pneumophilia, Streptococcus pyogenes, Escherichia coli, Neisseria gonorrhoeae, Neisseria meningitidis, Pneumococcus spp., Hemophilis*

25   *influenzae B, Treponema pallidum,* Lyme disease spirochetes, *Pseudomonas aeruginosa, Mycobacterium leprae, Brucella abortus, Mycobacterium tuberculosis* or a *Mycoplasma.*

66.   The method of claim 59, wherein the condition is an autoimmune disease.

67.   The method of claim 66, wherein the autoimmune disease is acute idiopathic thrombocytopenic purpura, chronic idiopathic thrombocytopenic purpura,

30   dermatomyositis, Sydenham's chorea, myasthenia gravis, systemic lupus erythematosus, lupus nephritis, rheumatic fever, polyglandular syndromes, bullous pemphigoid, juvenile

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diabetes mellitus, Henoch-Schonlein purpura, post-streptococcalnephritis, erythema nodosurn, Takayasu's arteritis, Addison's disease, rheumatoid arthritis, multiple sclerosis, sarcoidosis, ulcerative colitis, erythema multiforme, IgA nephropathy, polyarteritis nodosa, ankylosing spondylitis, Goodpasture's syndrome, thromboangitisubiterans,

5   Sjogren's syndrome, primary biliary cirrhosis, Hashimoto's thyroiditis, thyrotoxicosis, scleroderma, chronic active hepatitis, polymyositis/dermatomyositis, polychondritis, pemphigus vulgaris, Wegener's granulomatosis, membranous nephropathy, amyotrophic lateral sclerosis, tabes dorsalis, giant cell arteritis/polymyalgia, pernicious anemia, rapidly progressive glomerulonephritis, psoriasis or fibrosing alveolitis.

10   68.   The method of claim 59, wherein the condition is myocardial infarction, ischemic heart disease, atherosclerotic plaques, graft rejection, Alzheimer's disease, atopic tissue or inflammation caused by accretion of activated granulocytes, monocytes, lymphoid cells or macrophages.

          69.   A method of diagnosing a condition comprising:

15   a)   obtaining a tetramer according to claim 34, wherein the first precursor binds to a target molecule, composite, aggregate, cell, antigen or tissue associated with the condition and the second precursor binds to a diagnostic hapten;

          b)   administering the tetramer to a subject suspected of having a condition;

          c)   administering to the same subject a diagnostic hapten that binds to the

20   second precursor; and

          d)   detecting the presence of the hapten bound to the tetramer;

          wherein localization of the hapten to a tissue associated with the condition is diagnostic of the presence of the condition in the subject.

          70.   The method of claim 69, wherein the hapten is conjugated to a

25   radionuclide selected from the group consisting of ^{18}F, ^{45}Ti, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{89}Zr, ^{94m}Tc, ^{94}Tc, ^{99m}Tc, ^{111}In, ^{123}I, ^{125}I, $^{154-158}$Gd, ^{177}Lu, ^{32}P, ^{188}Re and ^{90}Y.

          71.   The method of claim 70, wherein the radionuclides are detected using an isotope detector or imaged using gamma scintigraphy, single photon emission computed tomography or positron emission tomography.

30   72.   The method of claim 69, wherein the condition is cancer and the first precursor binds to a tumor-associated antigen selected from the group consisting of carbonic anhydrase IX, alpha-fetoprotein, A3, antigen specific for A33 antibody, Ba 733,

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BrE3-antigen, CA125, CD1, CD1a, CD3, CD5, CD15, CD16, CD19, CD20, CD21, CD22, CD23, CD25, CD30, CD33, CD45, CD74, CD79a, CD80, CD138, colon-specific antigen-p (CSAp), CEA (CEACAM5), CEACAM6, CSAp, EGFR, EGP-1, EGP-2, Ep-CAM, Flt-1, Flt-3, folate receptor, G250 antigen, HLA-DR, human chorionic

5   gonadotropin (HCG) and its subunits, HER2/neu, hypoxia inducible factor (HIF-1), Ia, IL-2, IL-6, IL-8, insulin growth factor-1 (IGF-1), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, macrophage inhibition factor (MIF), MAGE, MUC1, MUC2, MUC3, MUC4, NCA66, NCA95, NCA90, antigen specific for PAM-4 antibody, placental growth factor, p53, prostatic acid phosphatase, PSA, PSMA, RS5, S100, TAC, TAG-72, tenascin, TRAIL

10   receptors, Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGF, ED-B fibronectin, 17-1A-antigen, an angiogenesis marker, an oncogene marker and an oncogene product.

73.   The method of claim 69, wherein the hapten is conjugated to a magnetic resonance imaging (MRI) contrast agent and the hapten bound to tetramer is detected by

15   MRI.

74.   The method of claim 73, wherein the MRI contrast agent is chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysporium (III), holmium (III) or erbium (III).

20   75.   The method of claim 69, wherein the hapten is conjugated to an ultrasound imaging enhancing agent and the hapten bound to binary complex is detected by ultrasound imaging.

76.   The method of claim 69, wherein either the first precursor or the second precursor has a binding affinity for CD19, CD20, CD22 or IL-17.

25   77.   The method of claim 56, wherein administration of the tetramer induces apoptosis in a target cell population.

78.   The method of claim 77, wherein the tetramer comprises a combination of antibodies or antibody fragments selected from the group consisting of anti-CD74 X anti-CD20, anti-CD74 X anti-CD22, anti-CD22 X anti-CD20, anti-CD20 X anti-HLA-DR,

30   anti-CD19 X anti-CD20, anti-CD20 X anti-CD80, anti-CD2 X anti-CD25, anti-CD8 X anti-CD25, and anti-CD2 X anti-CD147.

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79.   The method of claim 77 wherein the first and/or second precursors have a
binding affinity for an antigen selected from the group consisting of CD2, CD3, CD8,
CD10, CD21, CD23, CD24, CD25, CD30, CD33, CD37, CD38, CD40, CD48, CD52,
CD55, CD59, CD70, CD74, CD80, CD86, CD138, CD147, HLA-DR, CEA, CSAp, CA-
5   125, TAG-72, EFGR, HER2, HER3, HER4, IGF-1R, c-Met, PDGFR, MUC1, MUC2,
MUC3, MUC4, TNFR1, TNFR2, NGFR, Fas (CD95), DR3, DR4, DR5, DR6, VEGF,
PIGF, ED-B fibronectin, tenascin, PSMA, PSA, carbonic anhydrase IX, and IL-6.

Figure 1

a) DDD1:

NH2-

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRL

REARA-*COOH* (SEQ ID NO:1)

b) DDD2:

NH2-

CGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTR

LREARA-*COOH* (SEQ ID NO:2)

Figure 2
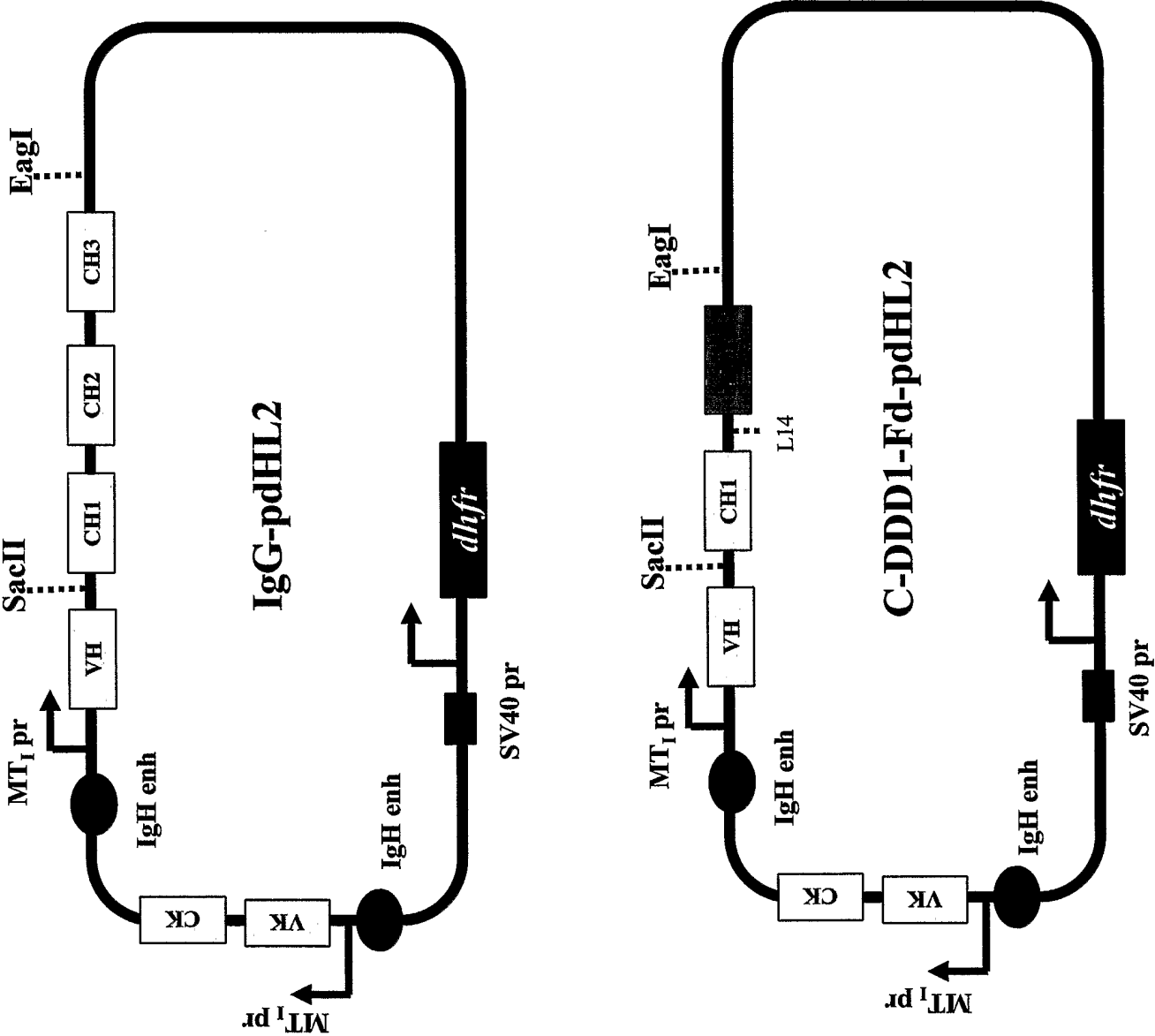
Figure 3
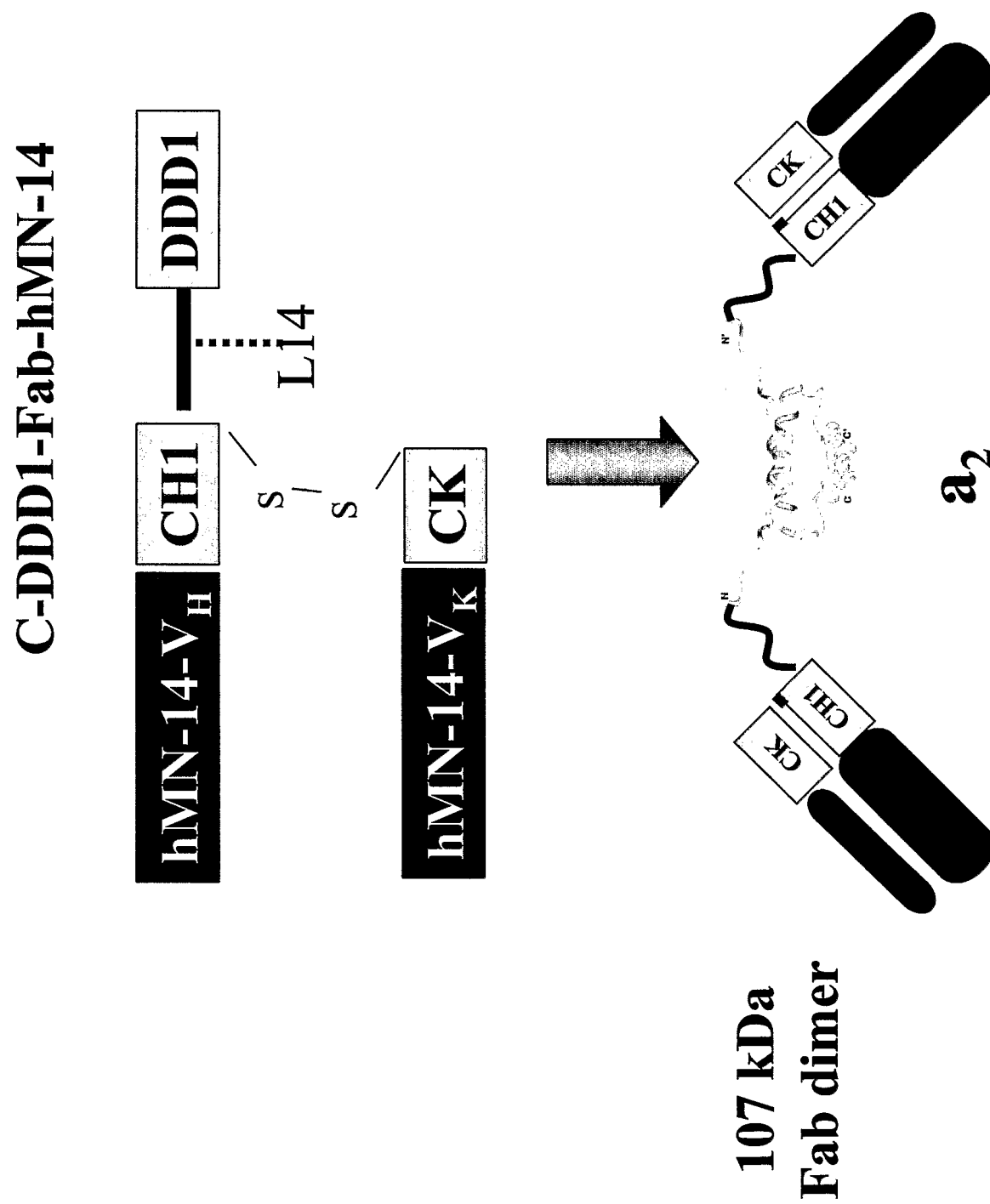
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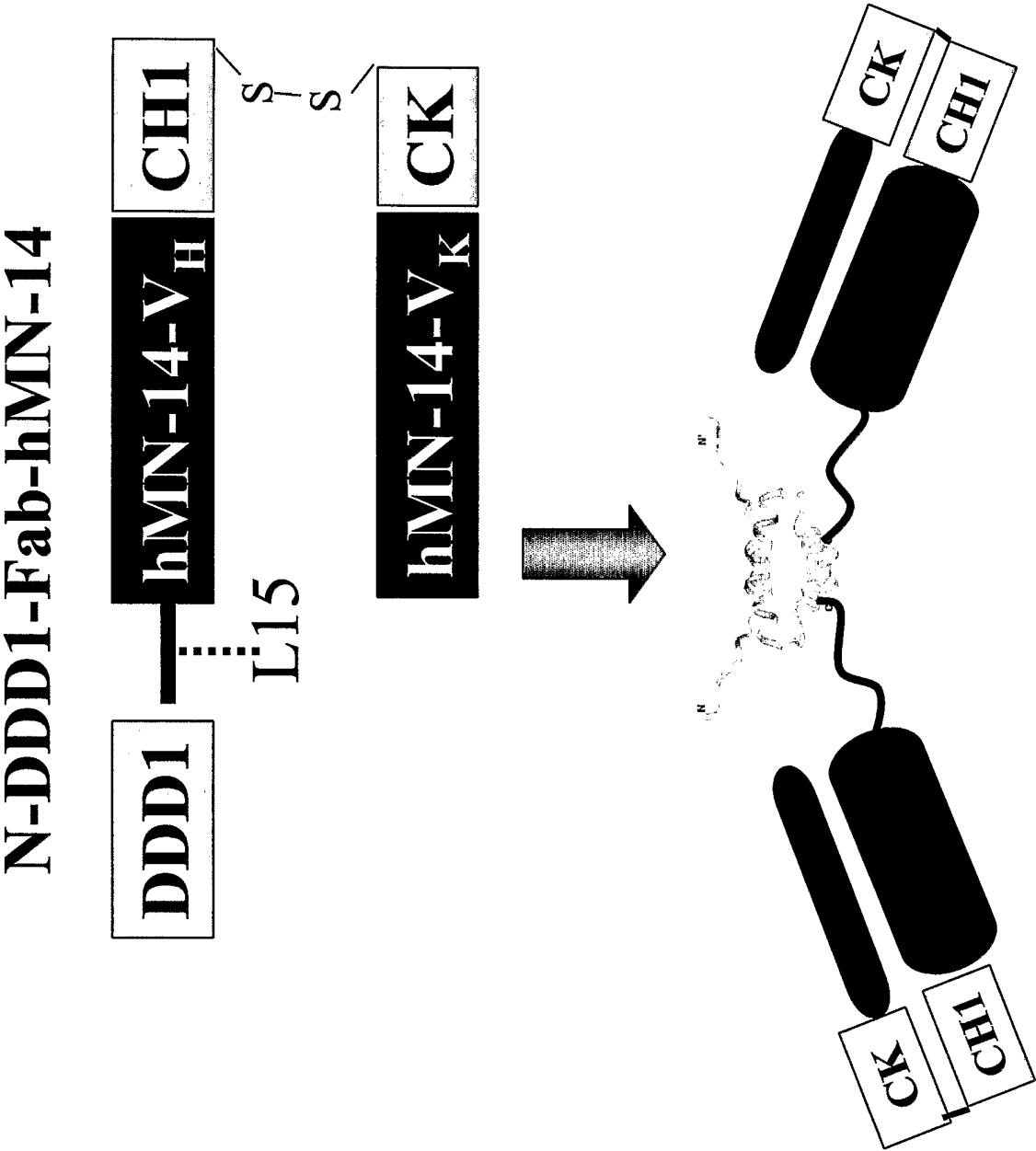
Figure 5

AD1-C:

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Figure 6

Single-Step Affinity Purification of
C-DDD1-Fab-hMN-14 With AD1-C-Affigel
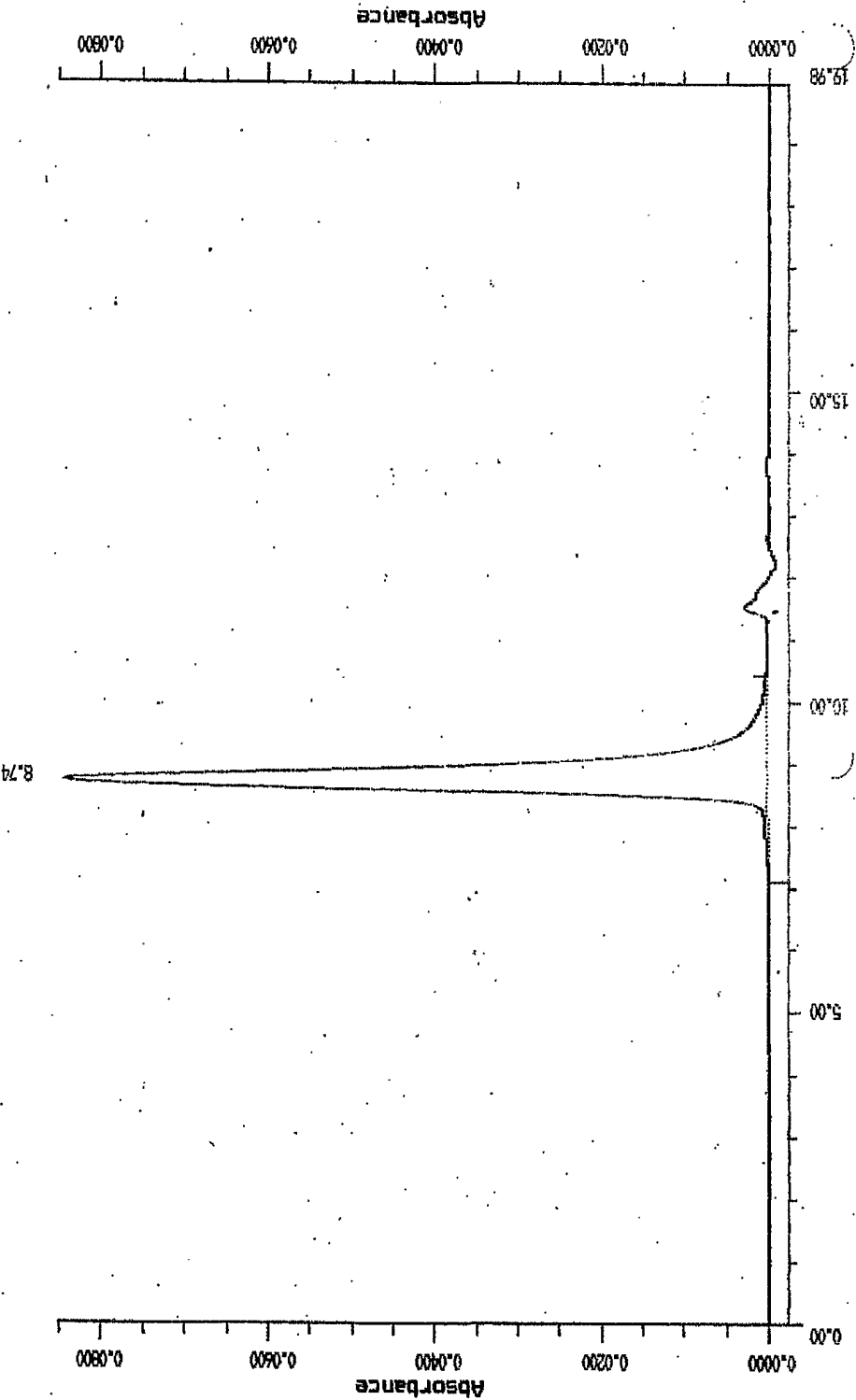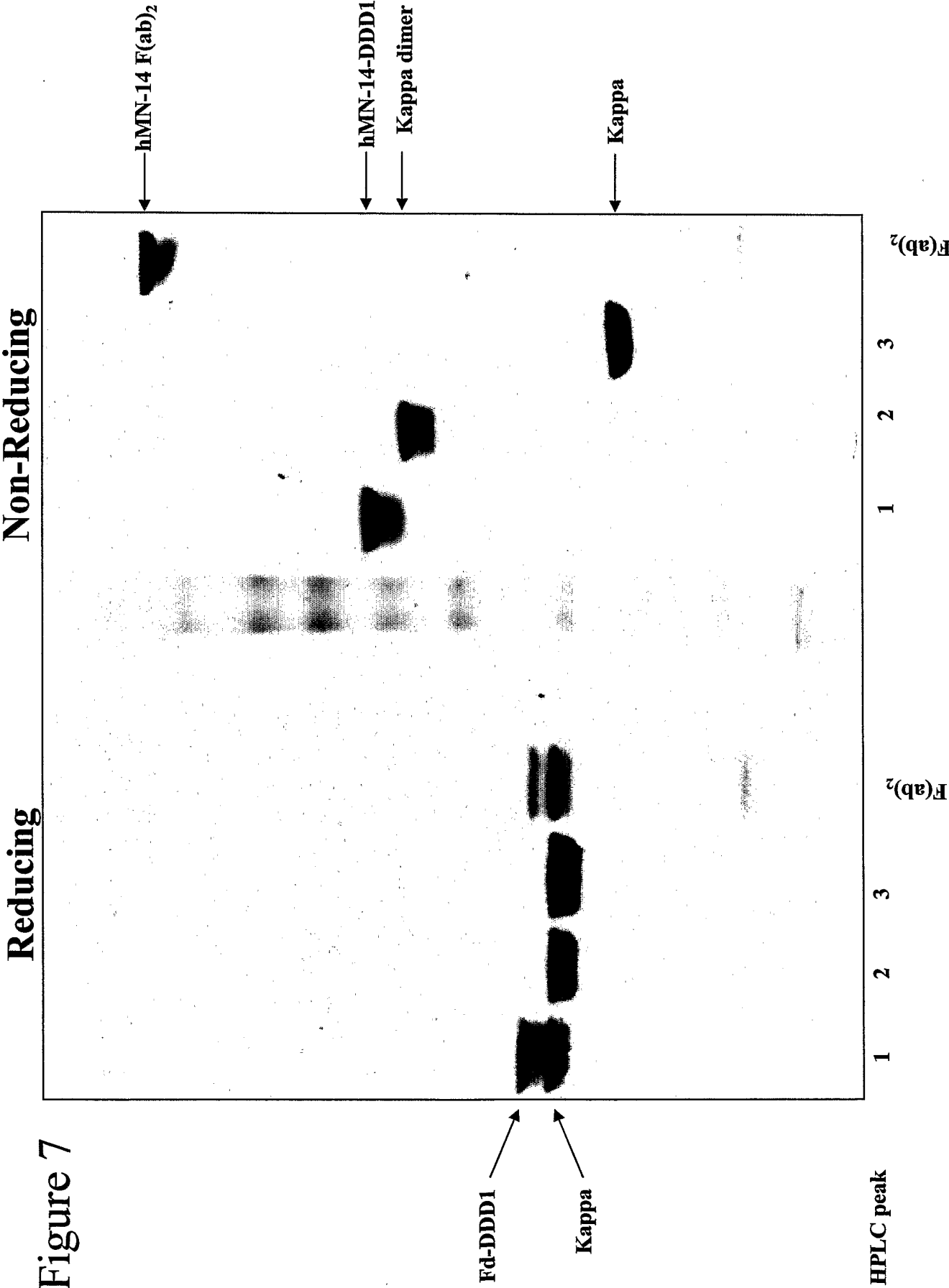
Figure 7

Figure 8

Single-Step Affinity Purification of
N-DDD1-Fab-hMN-14 with AD1-C Affigel
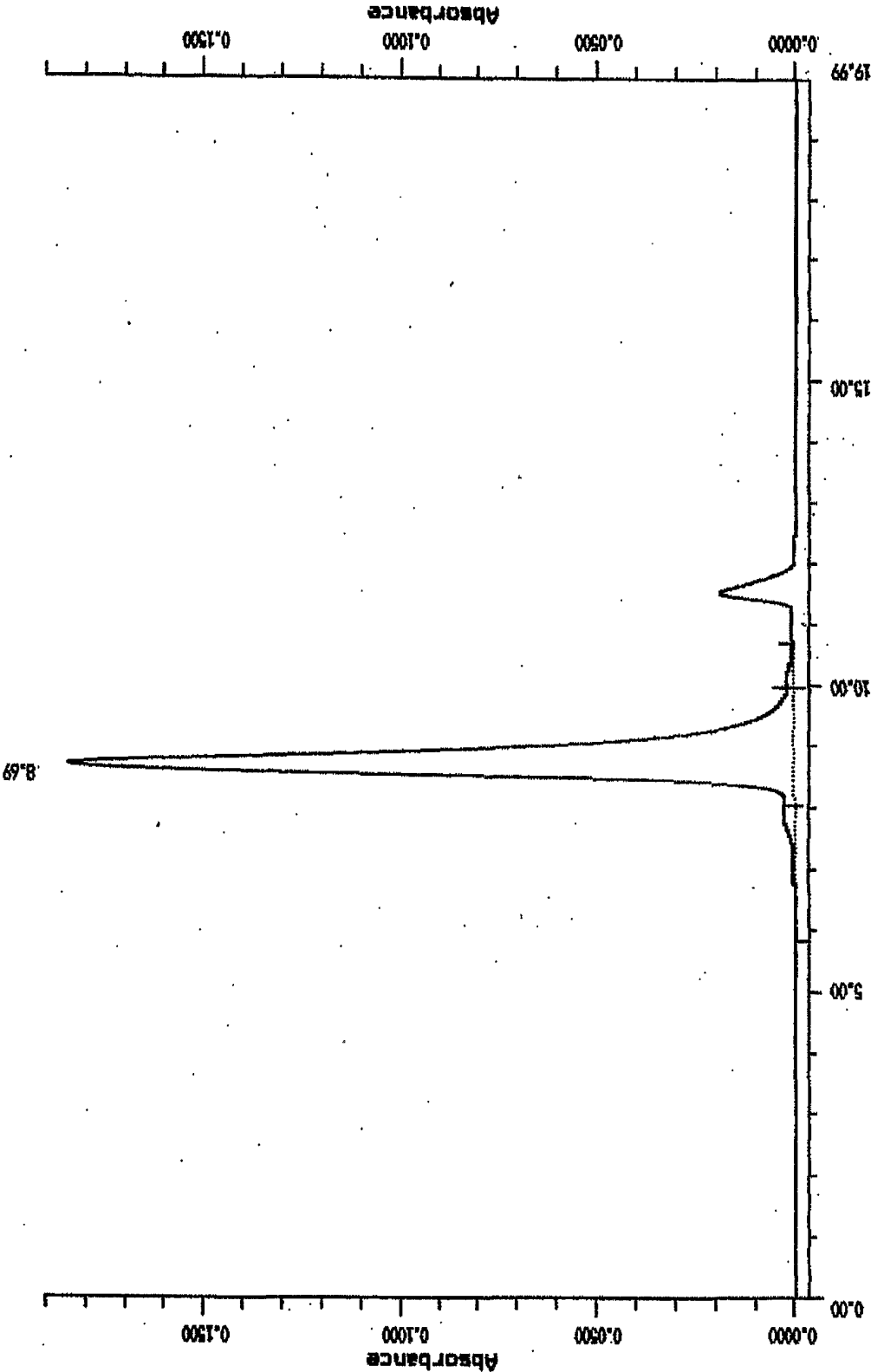
Figure 9

C-DDD1-Fab-hMN-14 forms an exclusive and stable a₂ dimer with two CEA binding Fabs

W12 Fab + hMN-14-DDD1
4 : 1 Ratio

7.36 min----200 kDa

W12 Fab + hMN-14-DDD1
0.75 : 1 Ratio
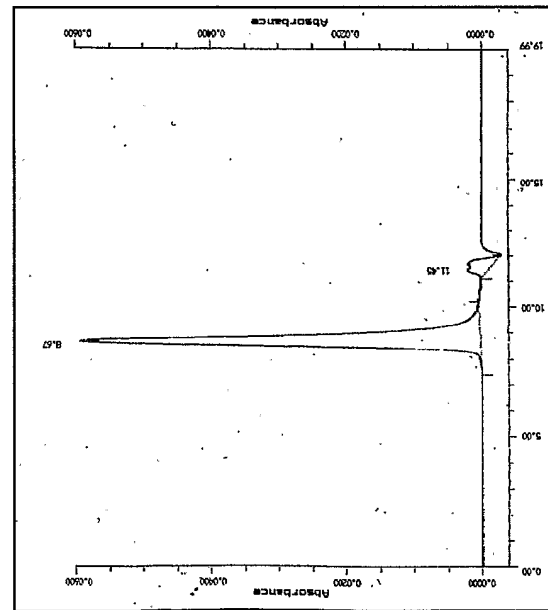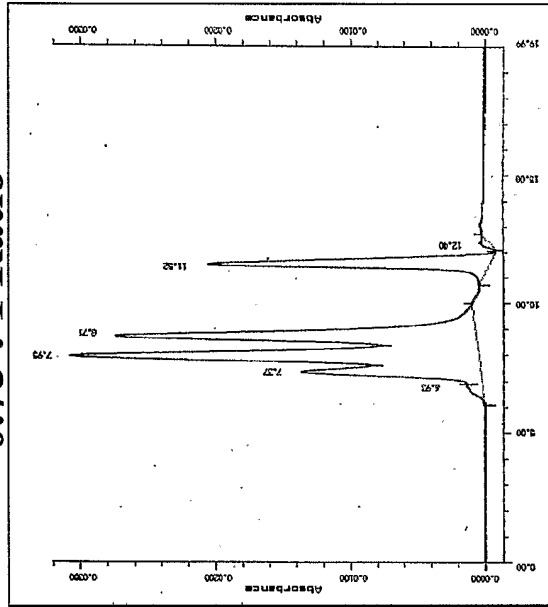
8.71 min----107 kDa
7.95 min----155 kDa
7.37 min----200 kDa

hMN-14-DDD1

8.67 min ----107 kDa
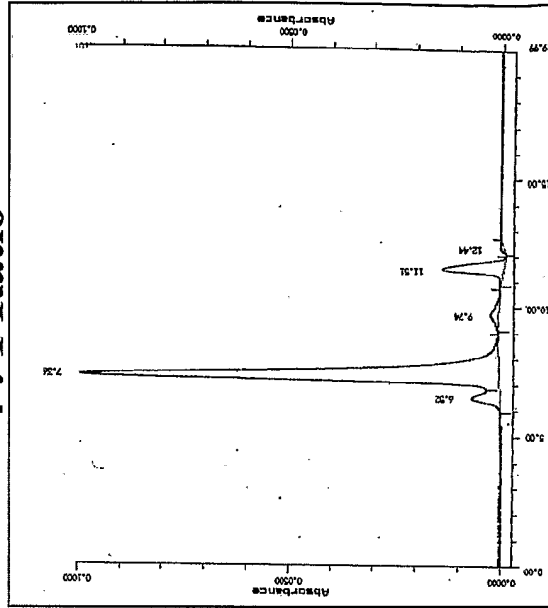
Figure 10

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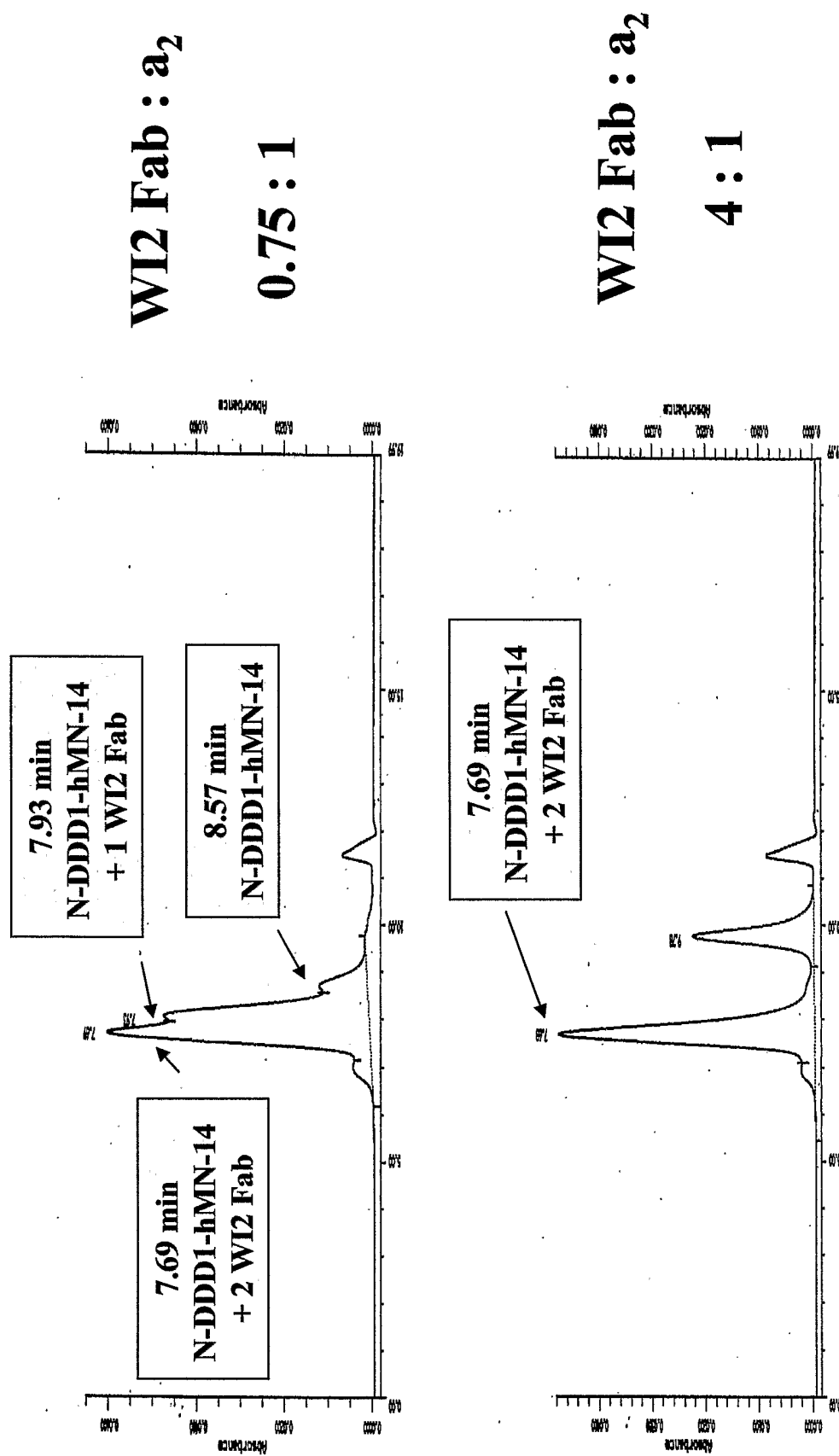
Figure 11

Competitive ELISA for CEA binding
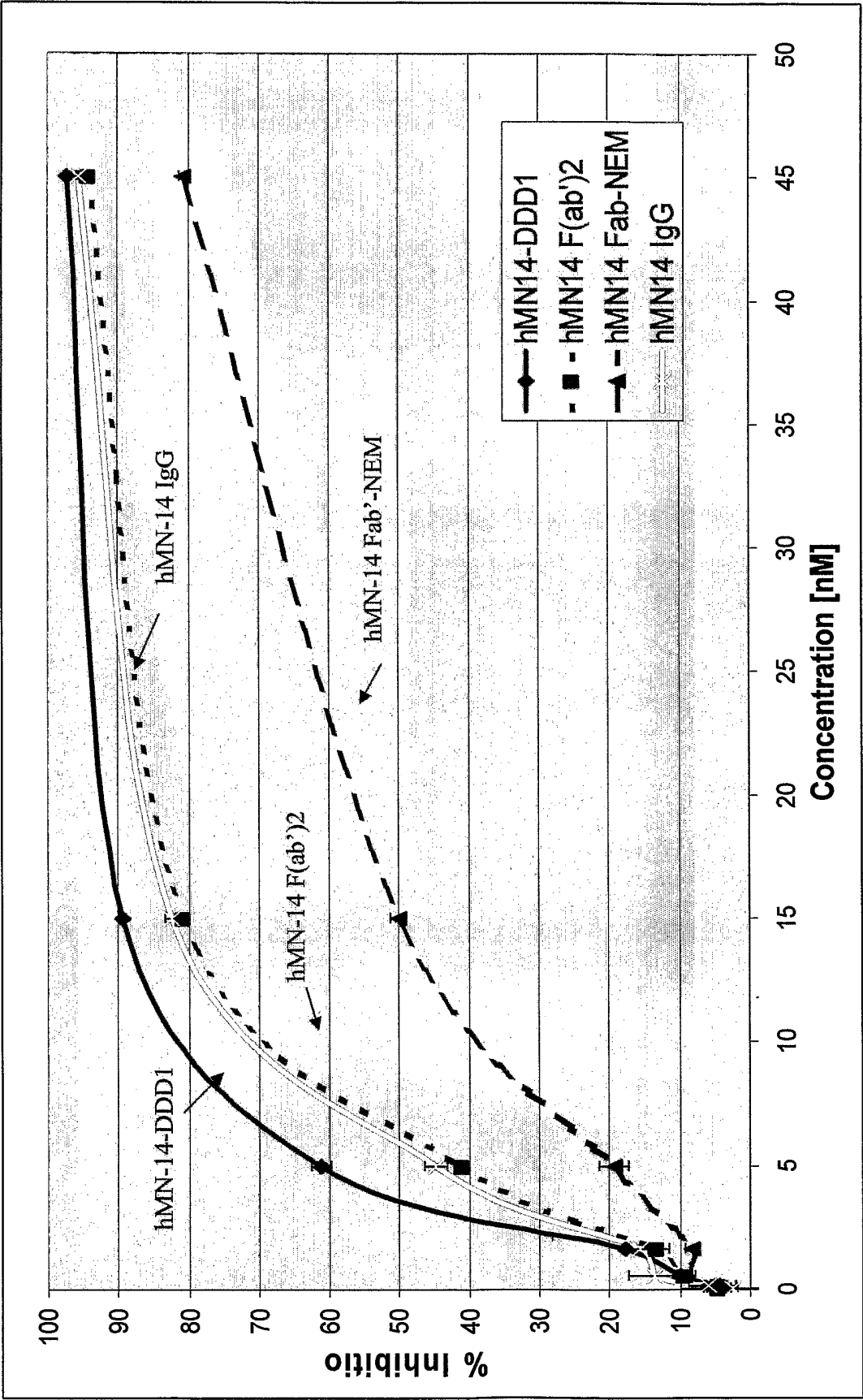
•Plates coated with hLL1-A3B3
Competition with HRP-hMN-14 IgG

Figure 12
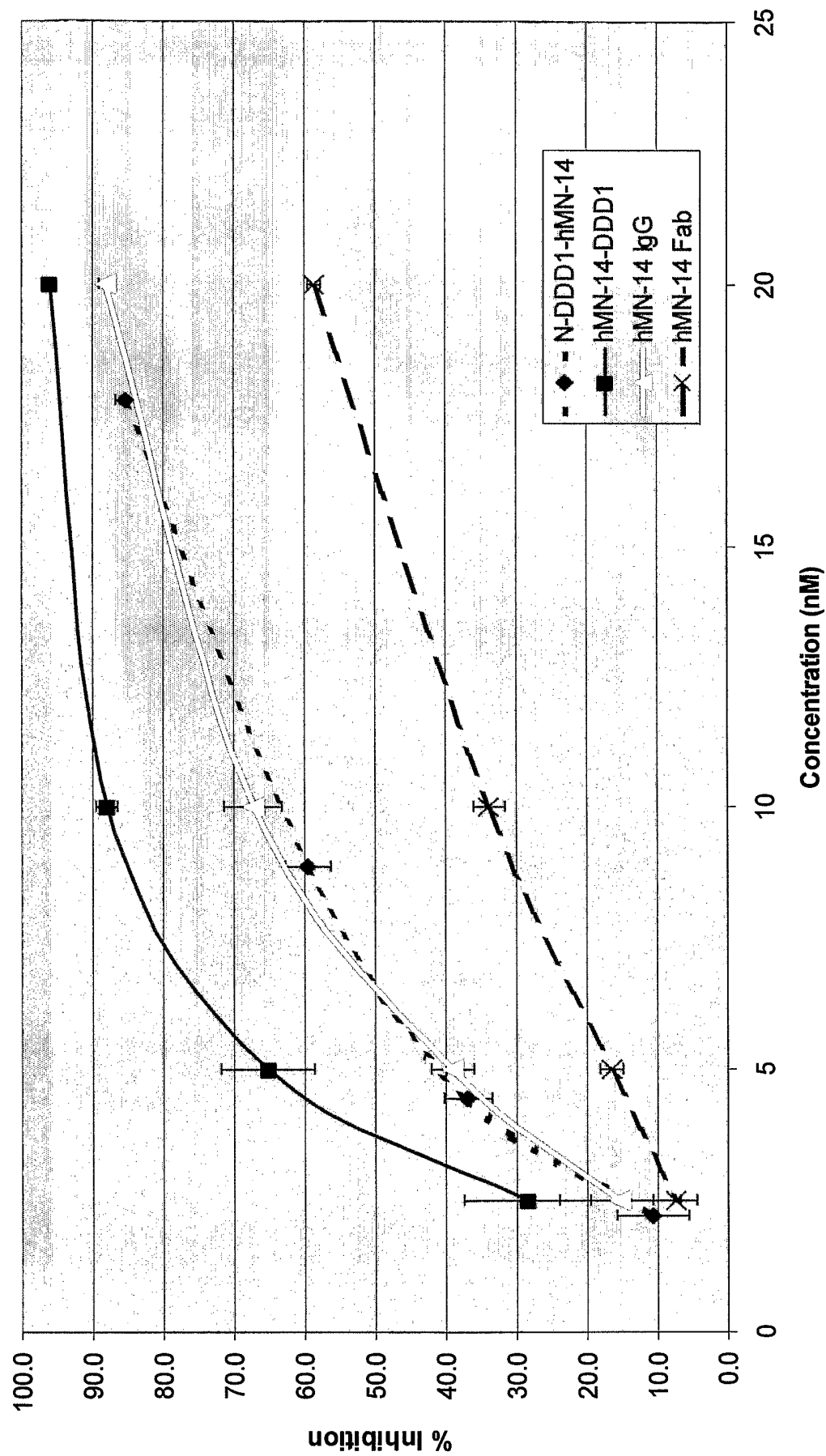
Figure 13 C-DDD1-Fab-hMN-14 Stability in Human Serum

T = 0
93% Recovery

T = 24 h
99% Recovery

T = 96 h
99% Recovery
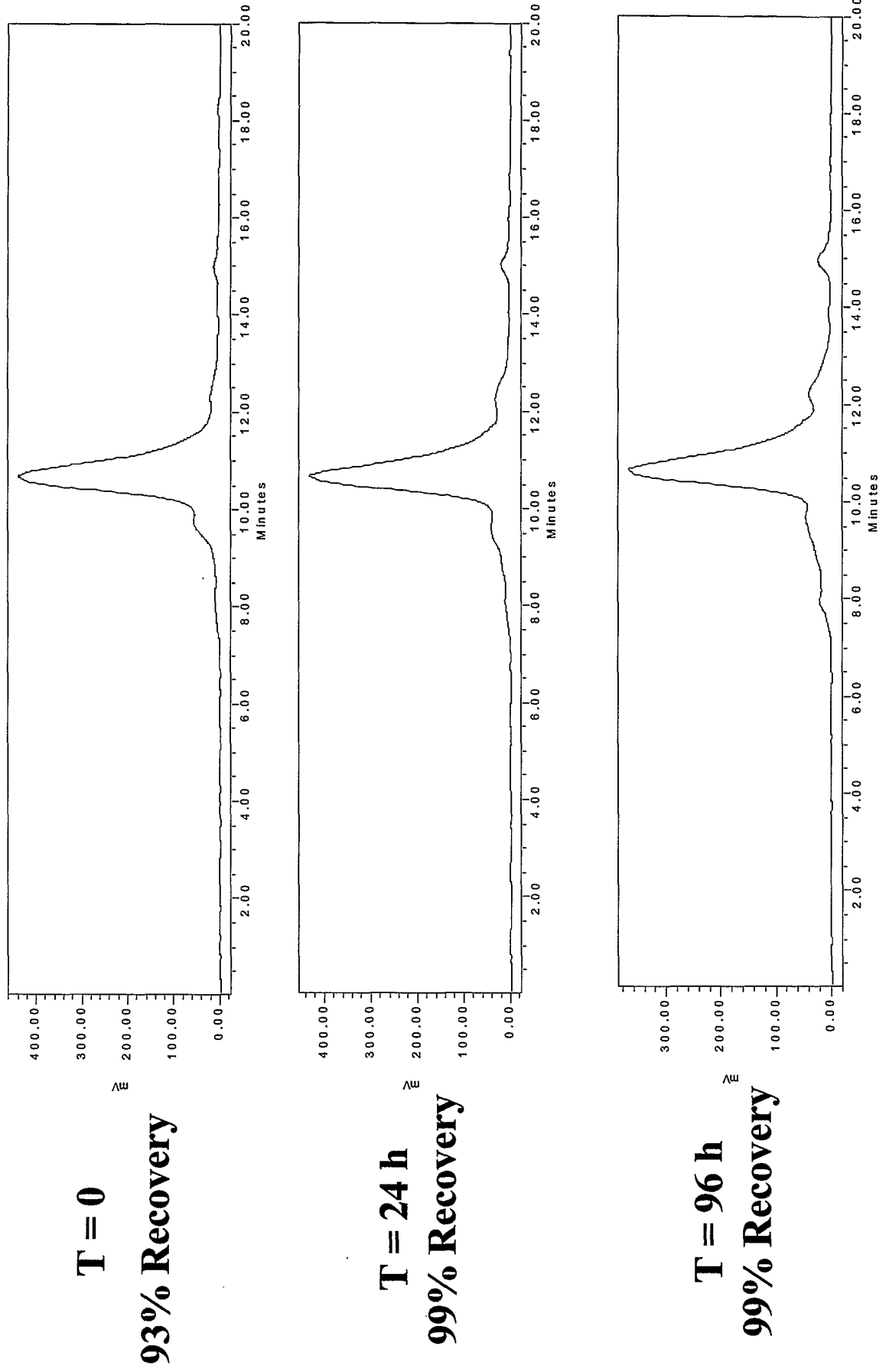
Figure 14

C-DDD1-Fab-hMN-14 Immunoreactivity
After 28 h in Human Serum

T = 24 h
99% Recovery
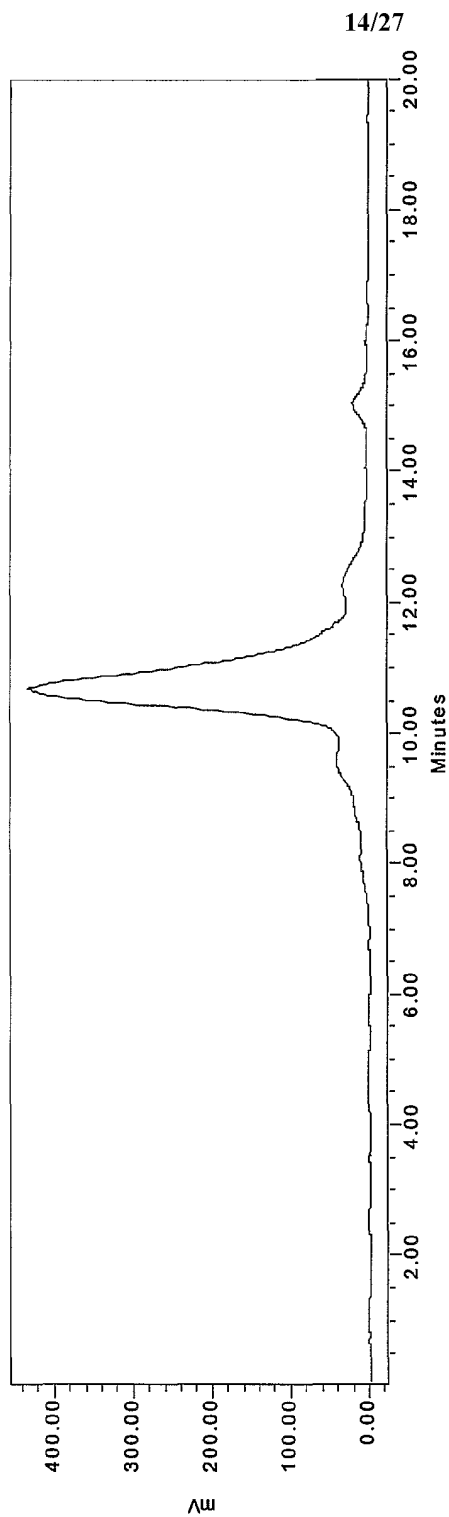
T = 28 h
+ WI2 Fab
99% Recovery
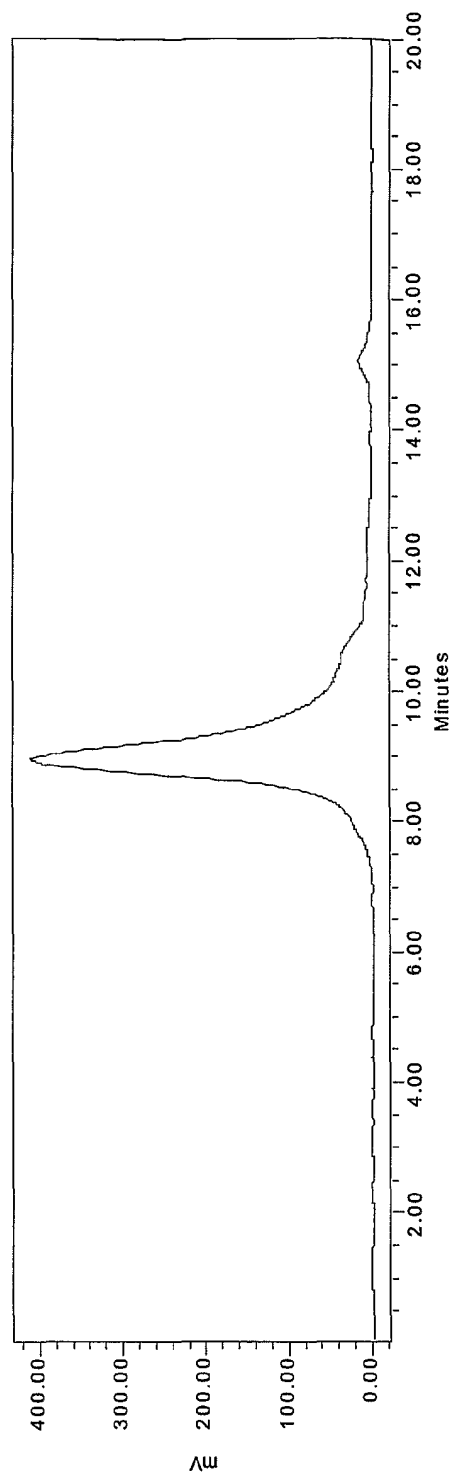
Figure 15

C-DDD1-Fab-hMN-14 in Nude mice bearing LS 174T xenografts

Tumor Uptake
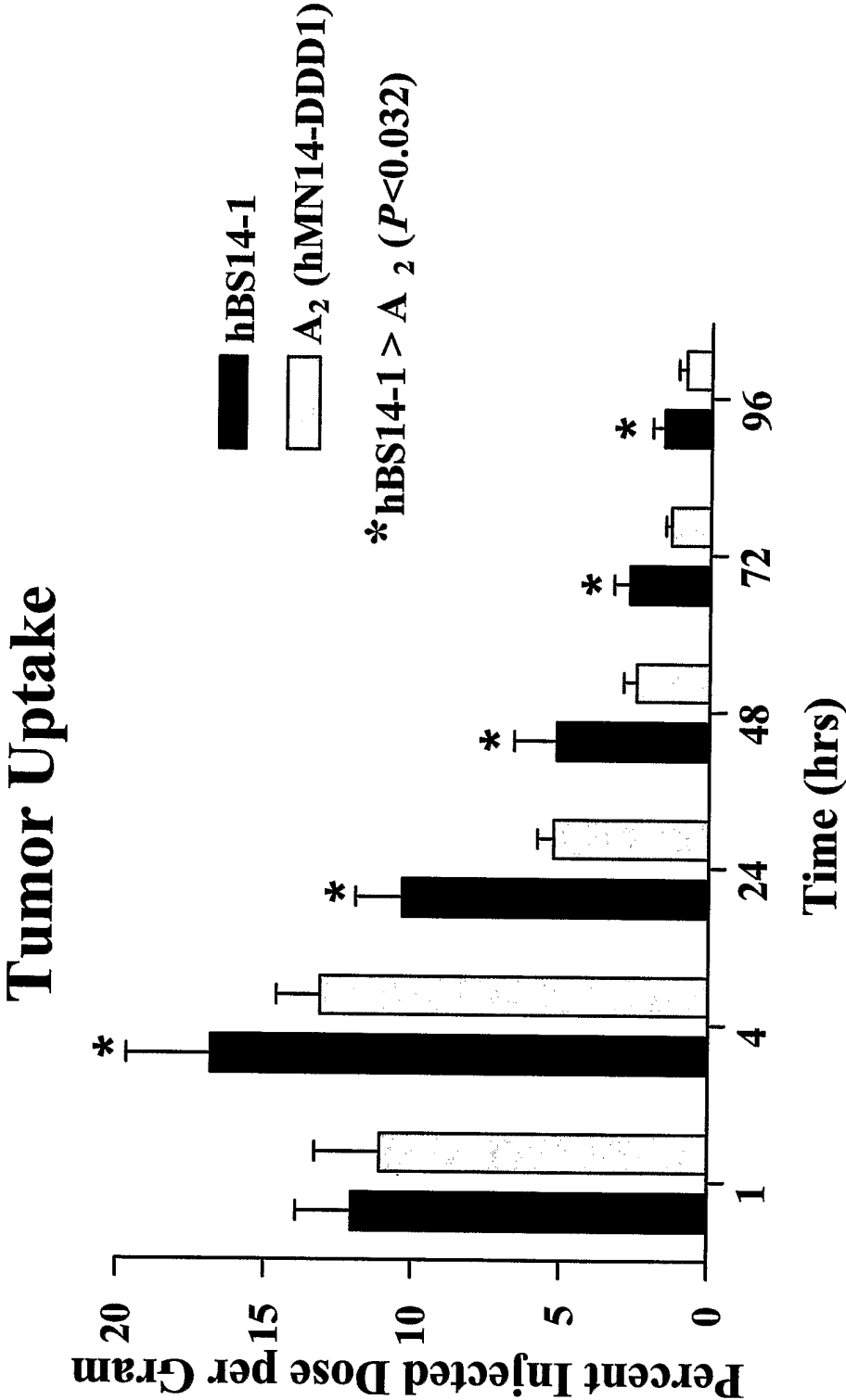
Figure 16

C-DDD1-Fab-hMN-14 uptake in key organs
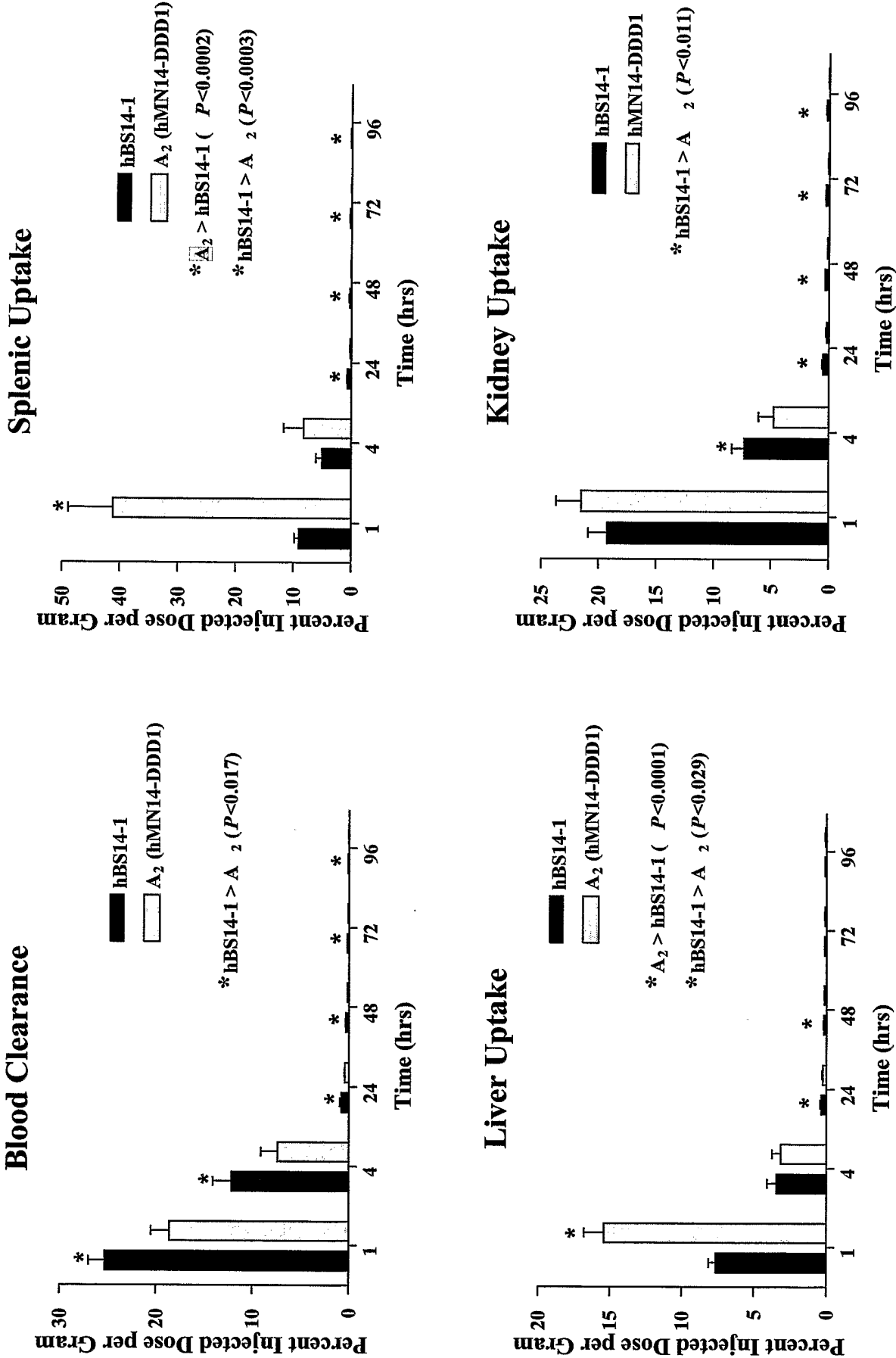
Figure 17

Rap-hPAM4-Fab-DDD1
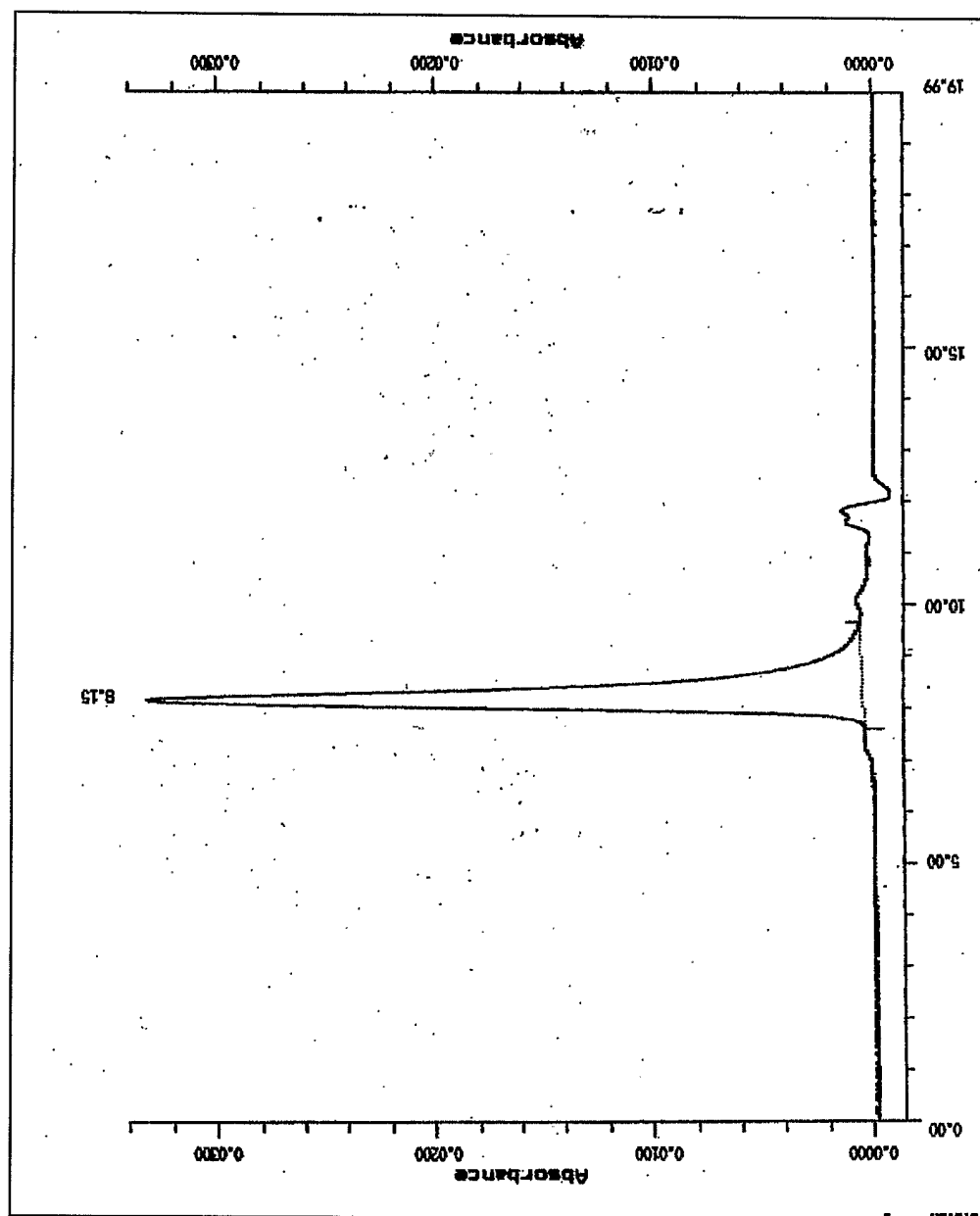
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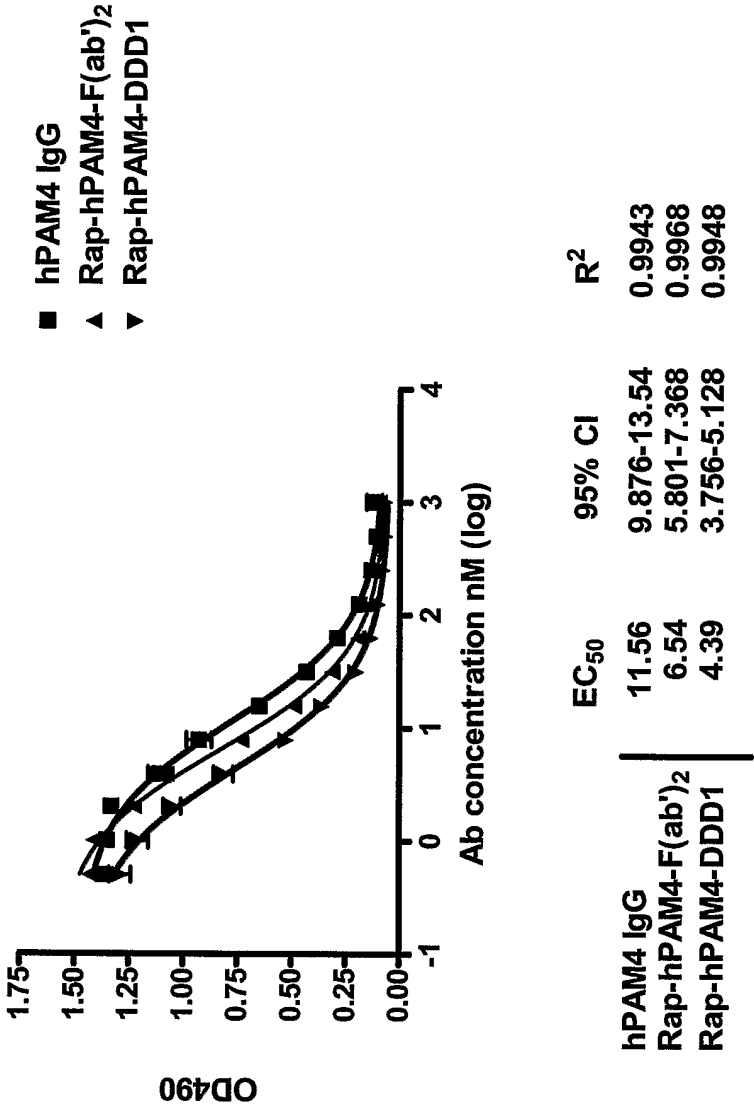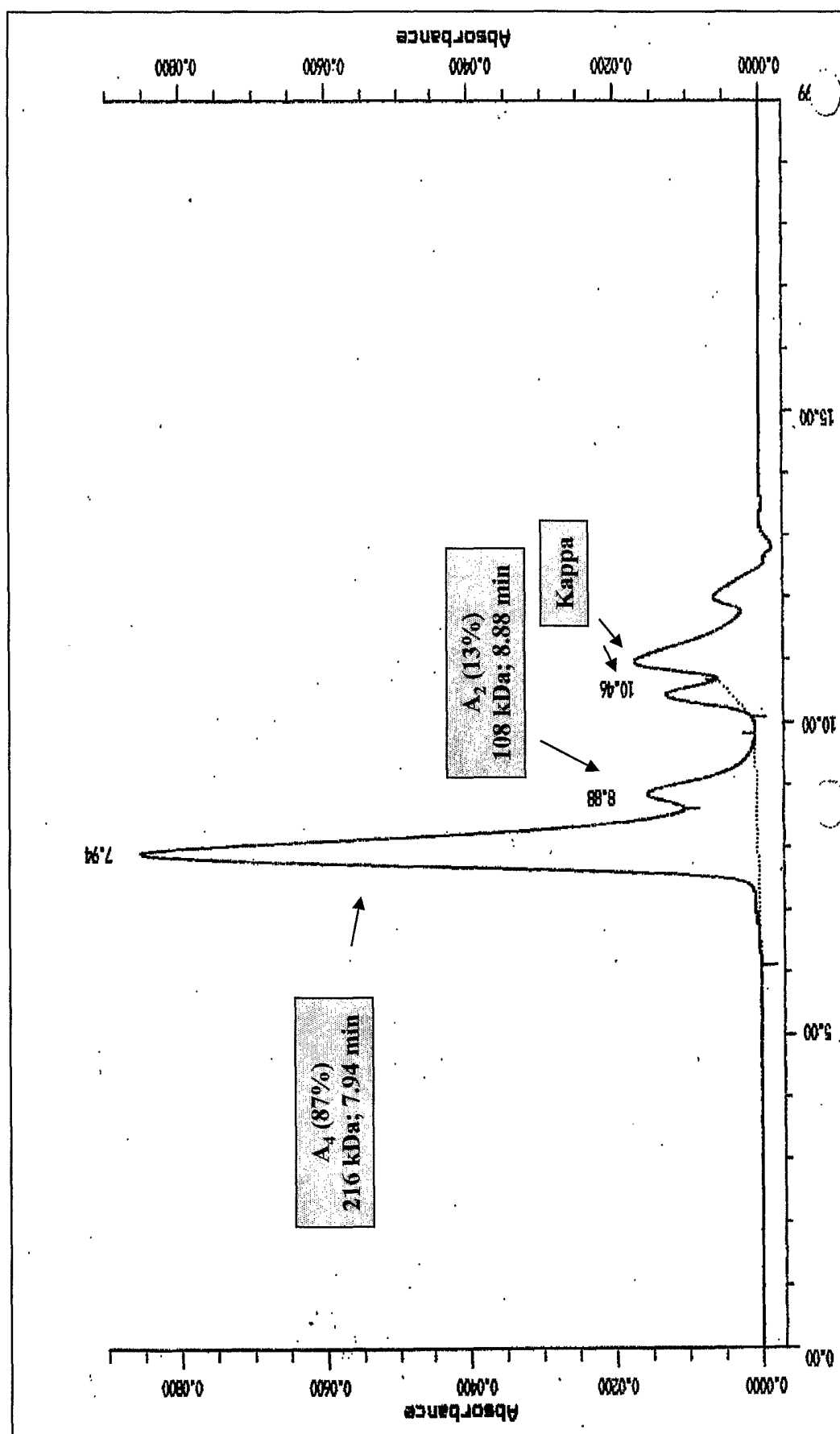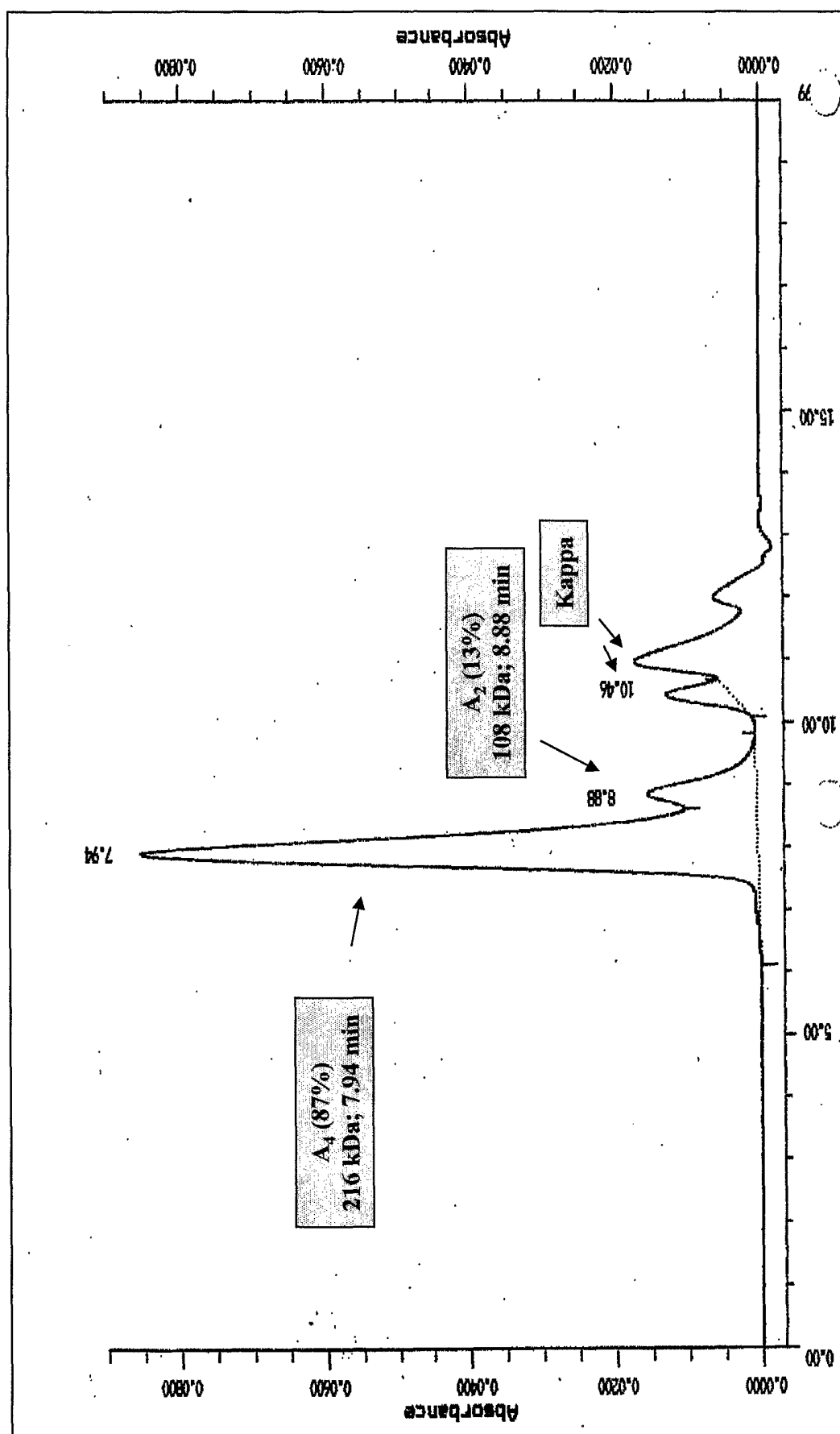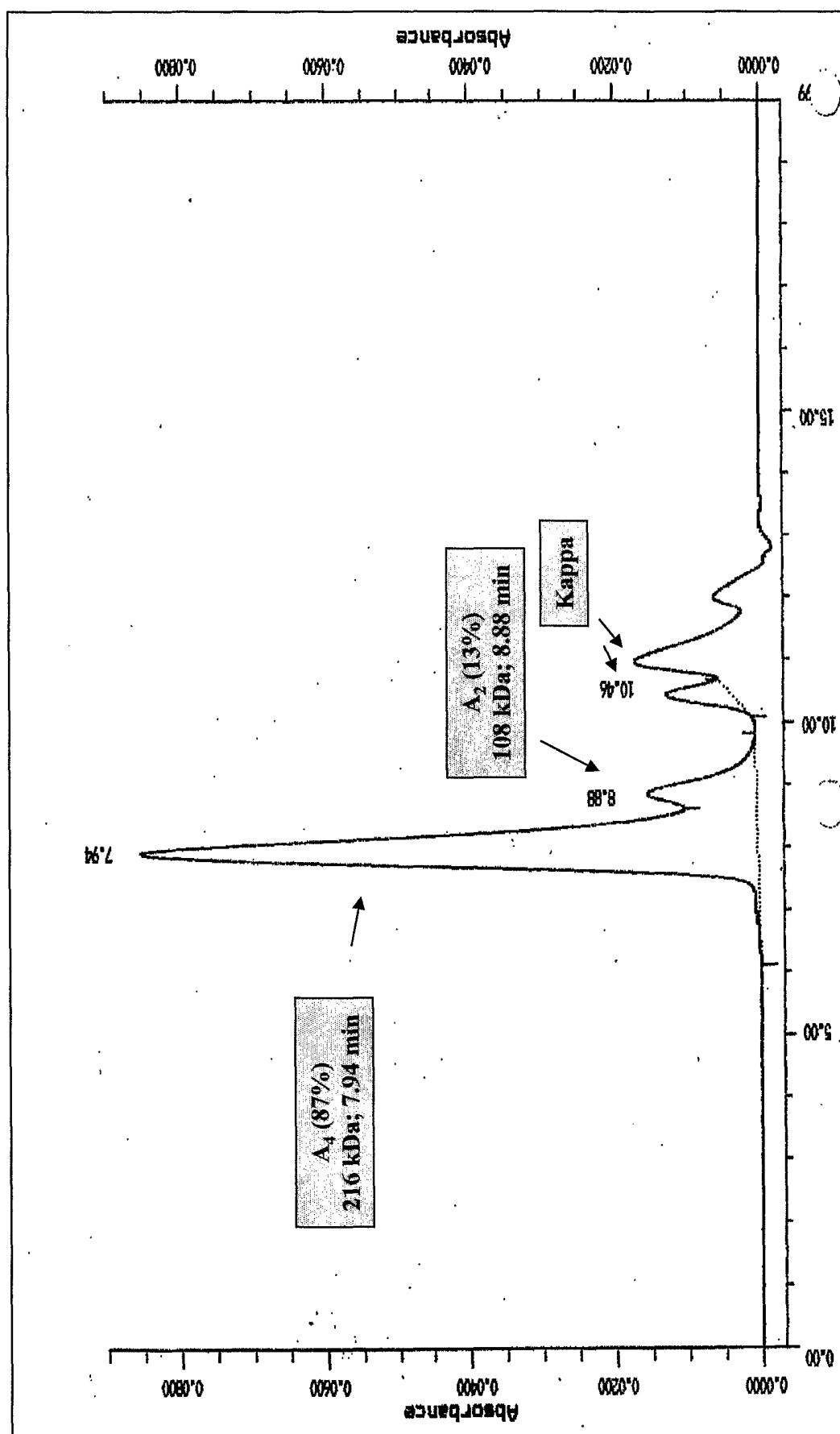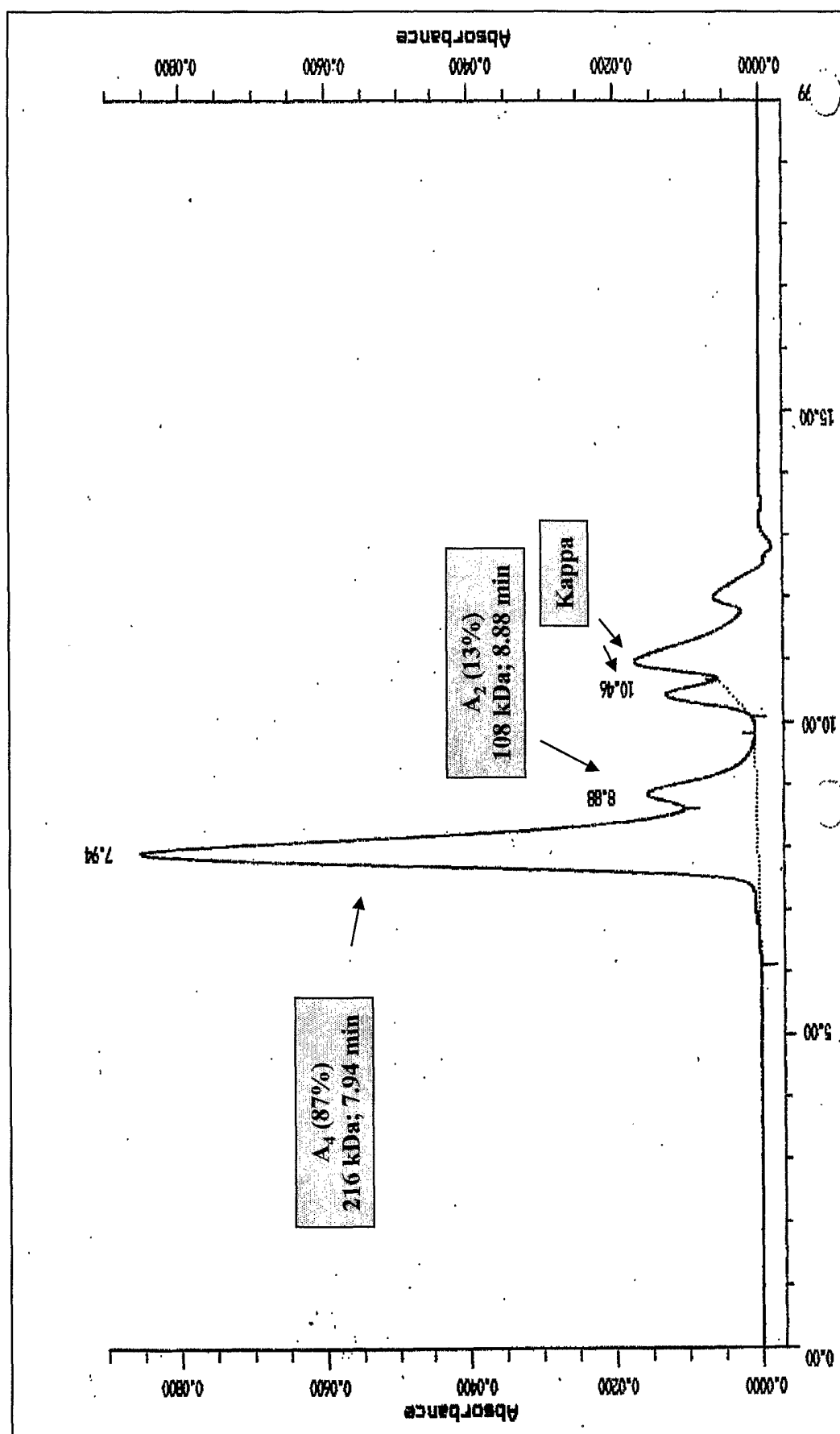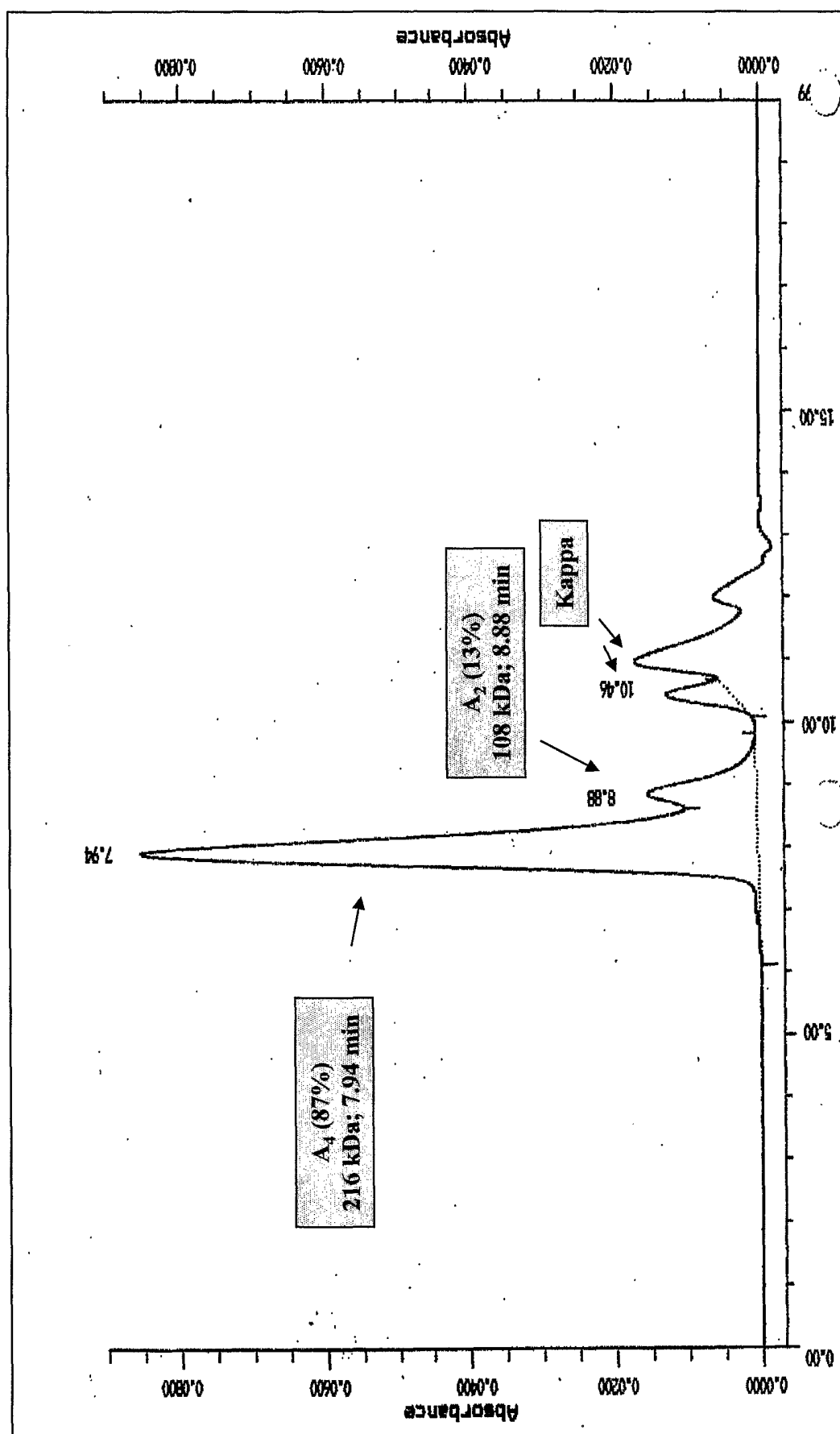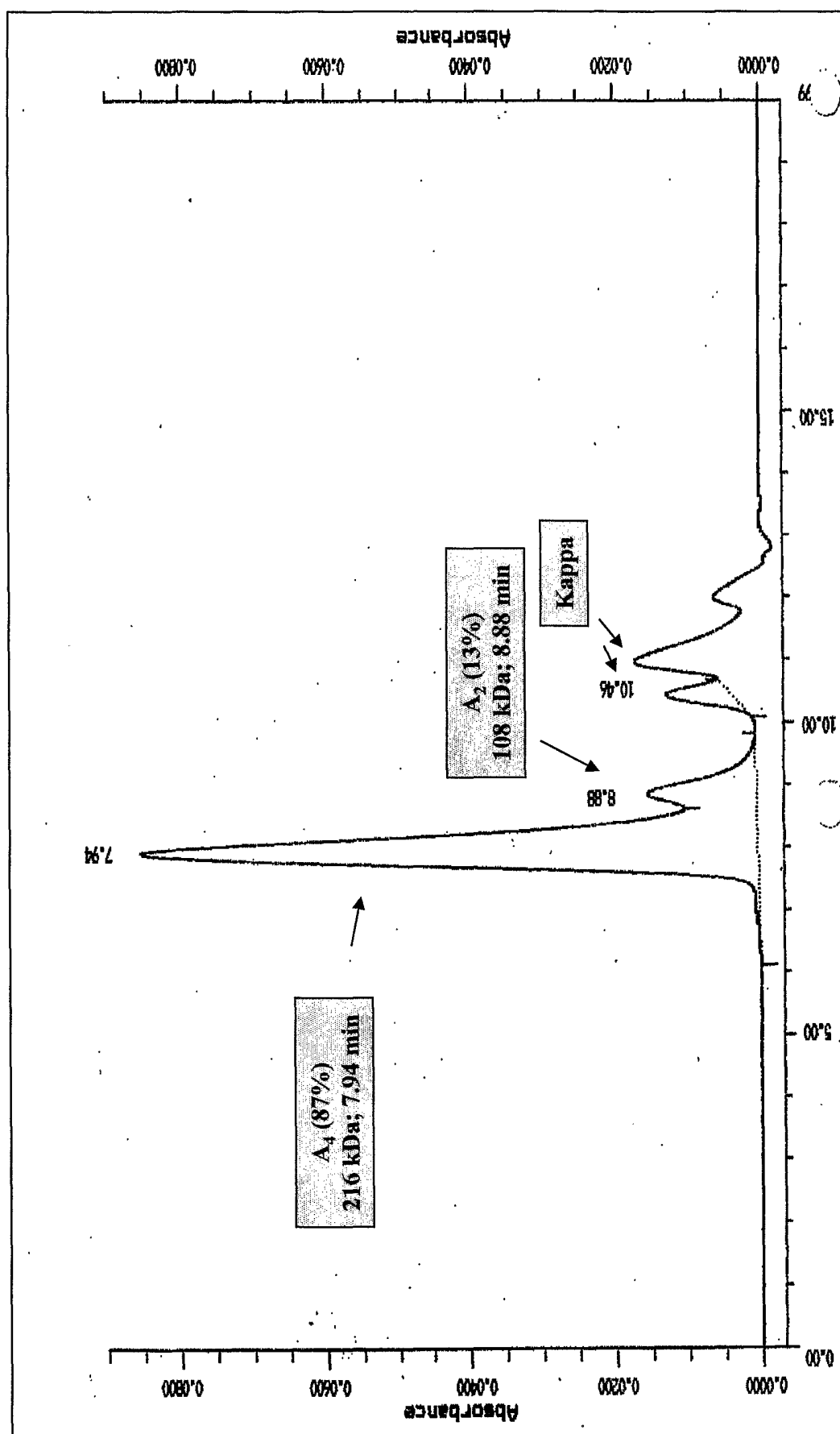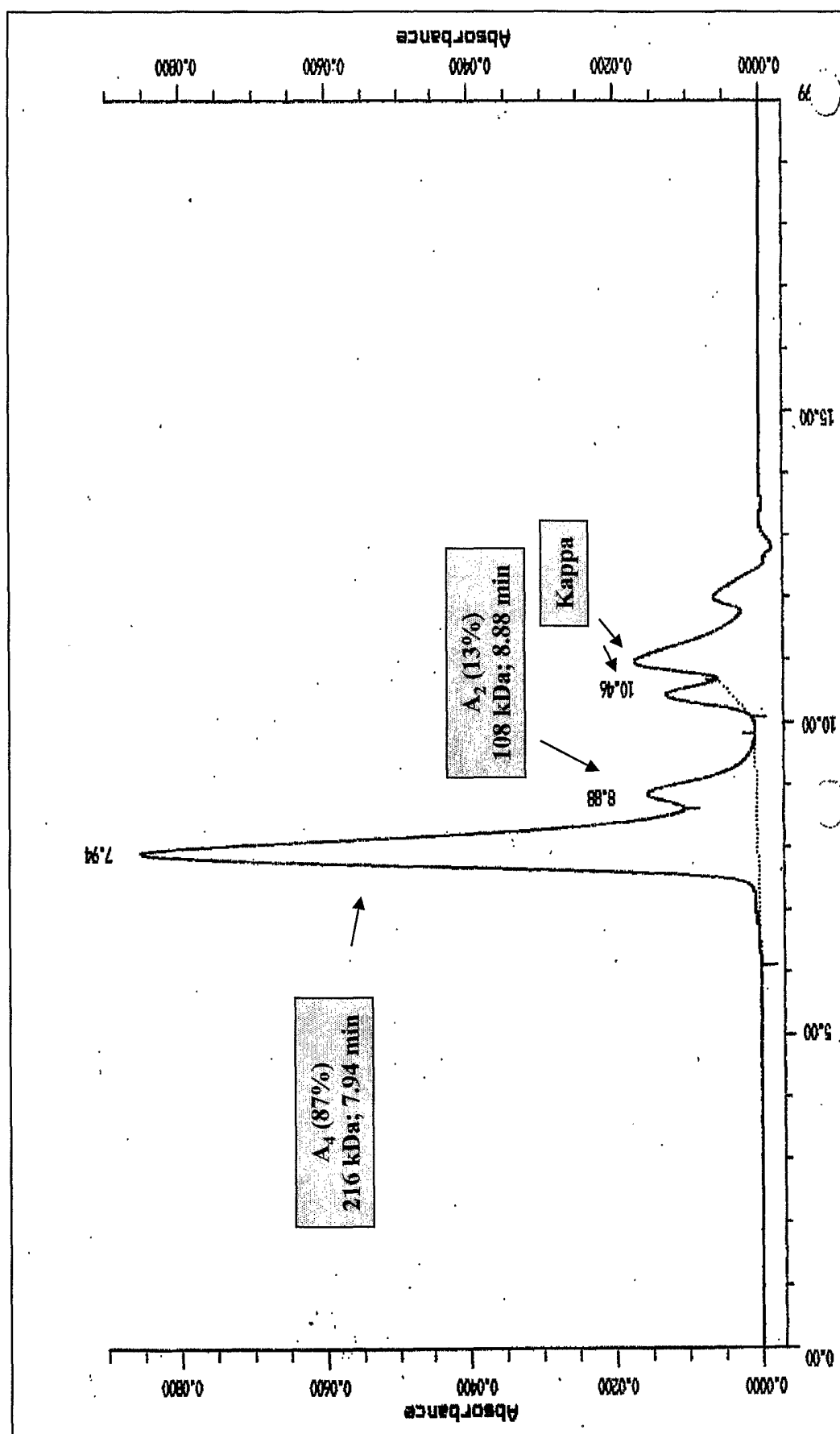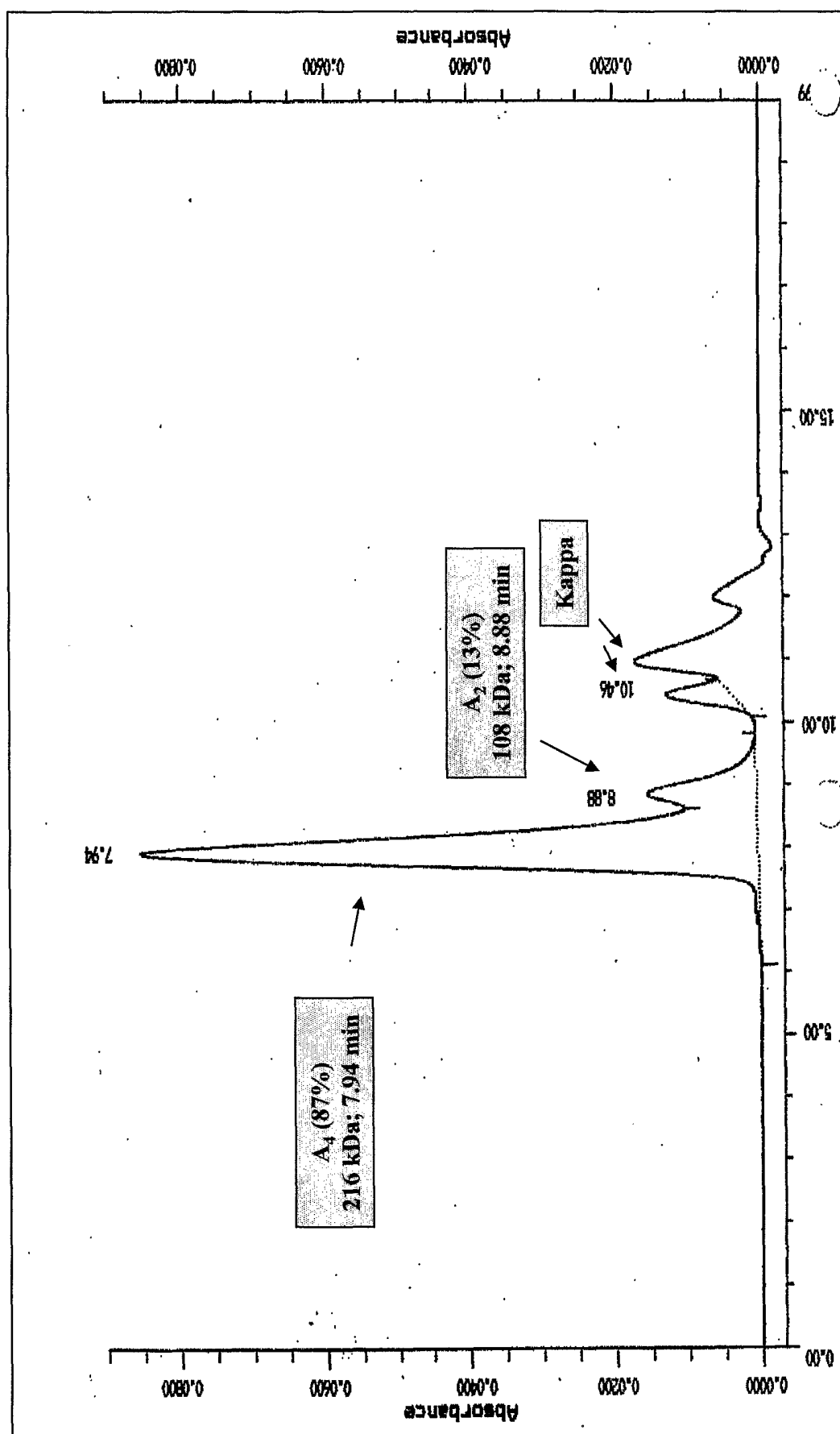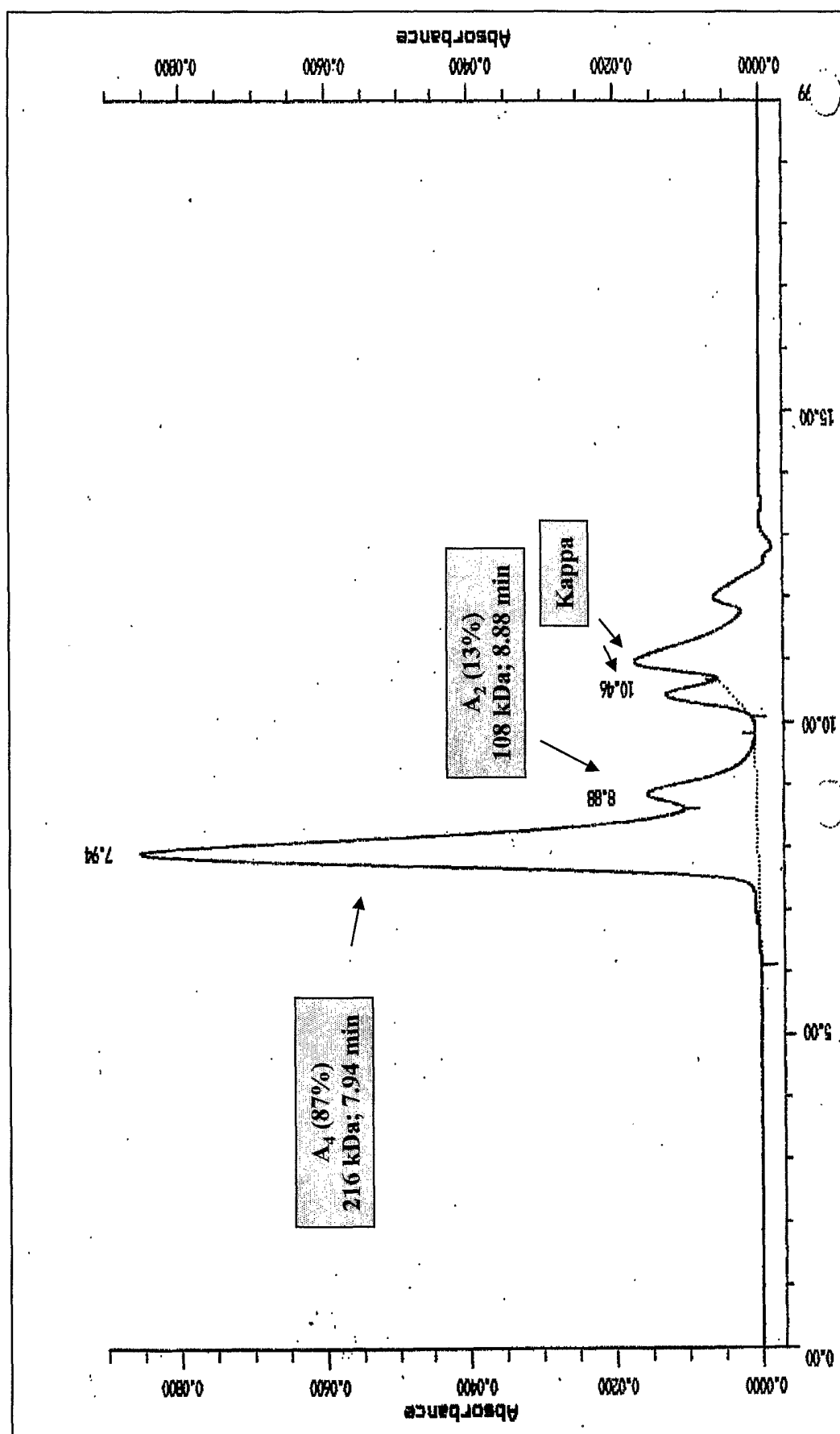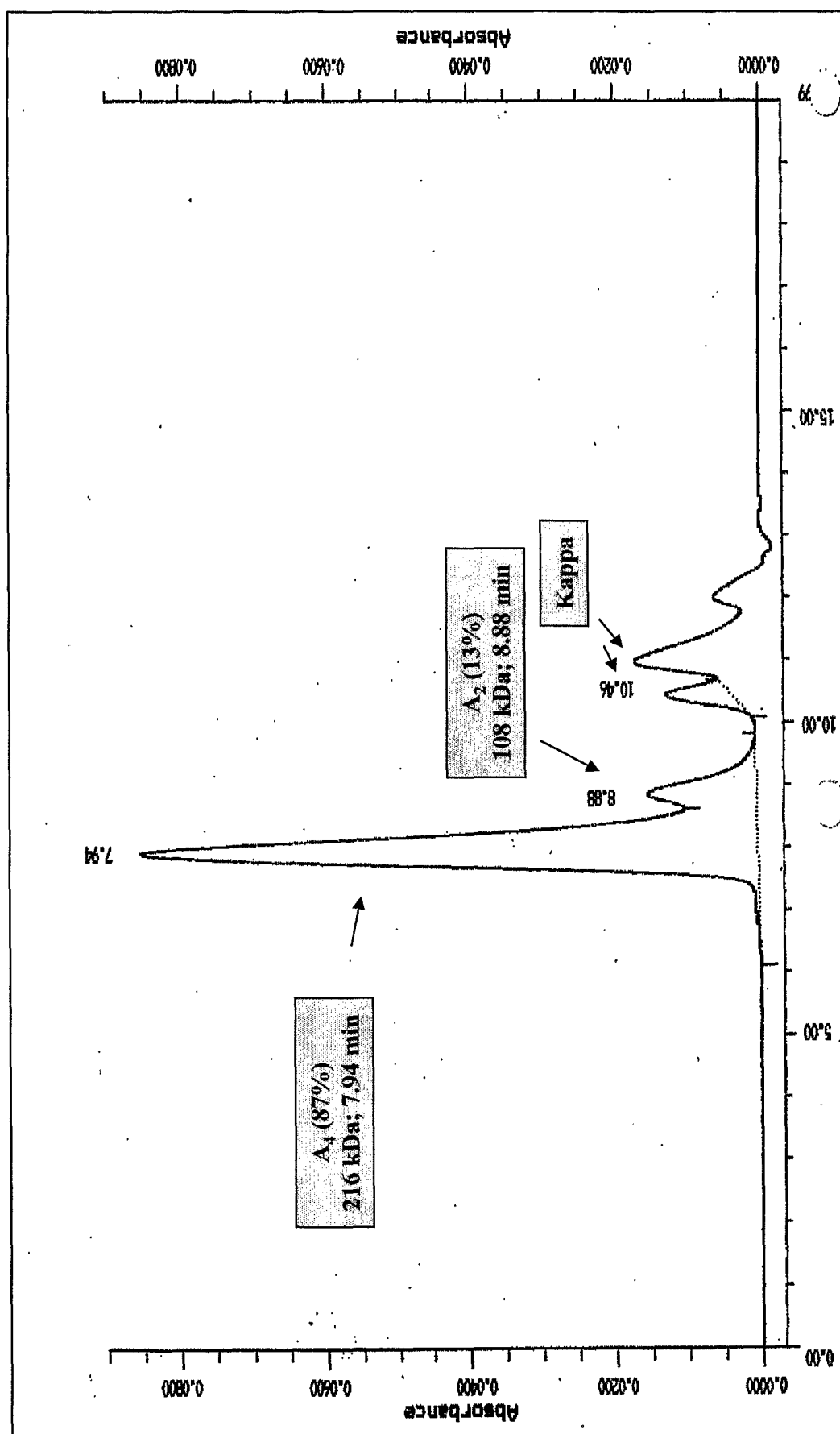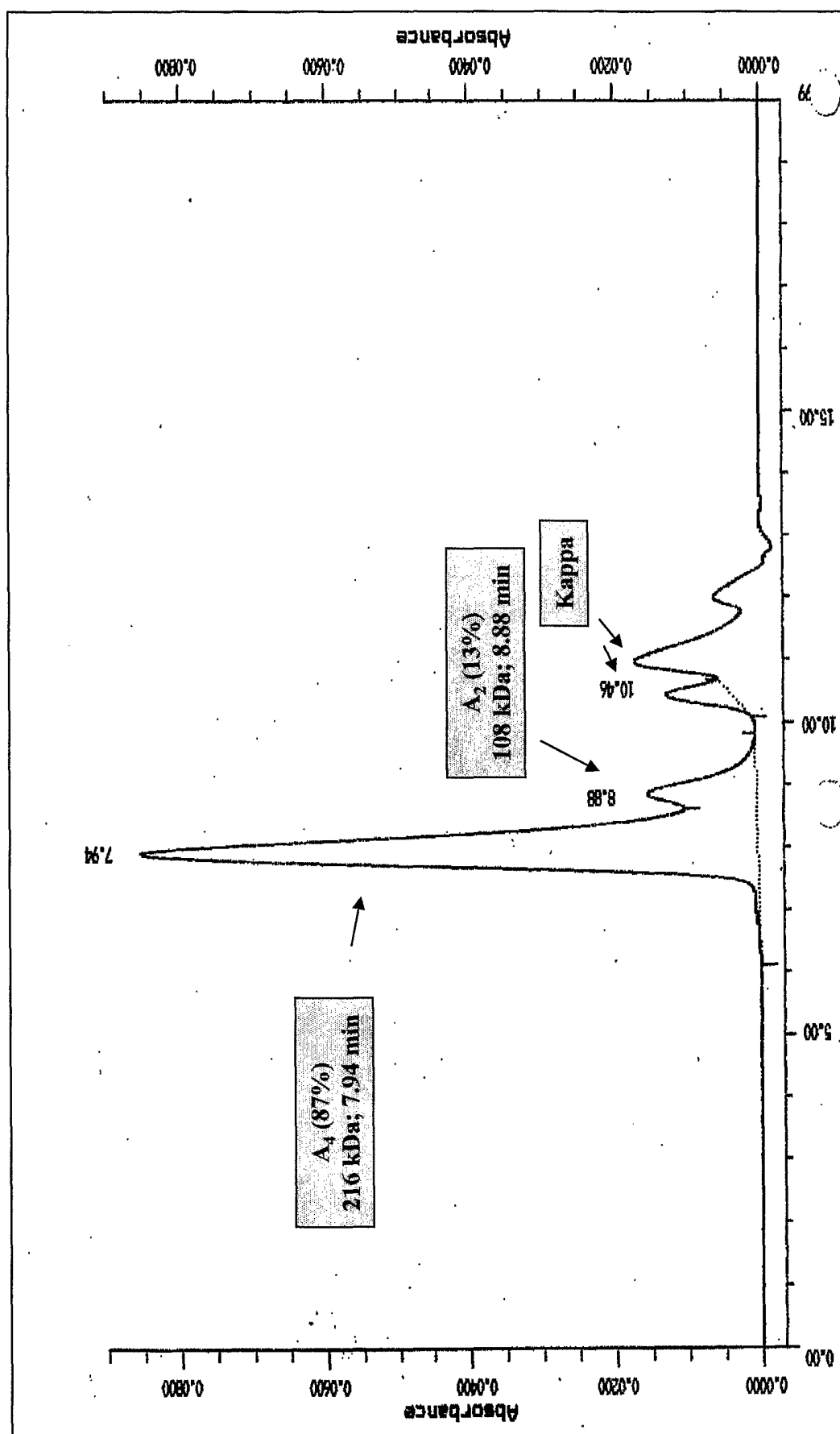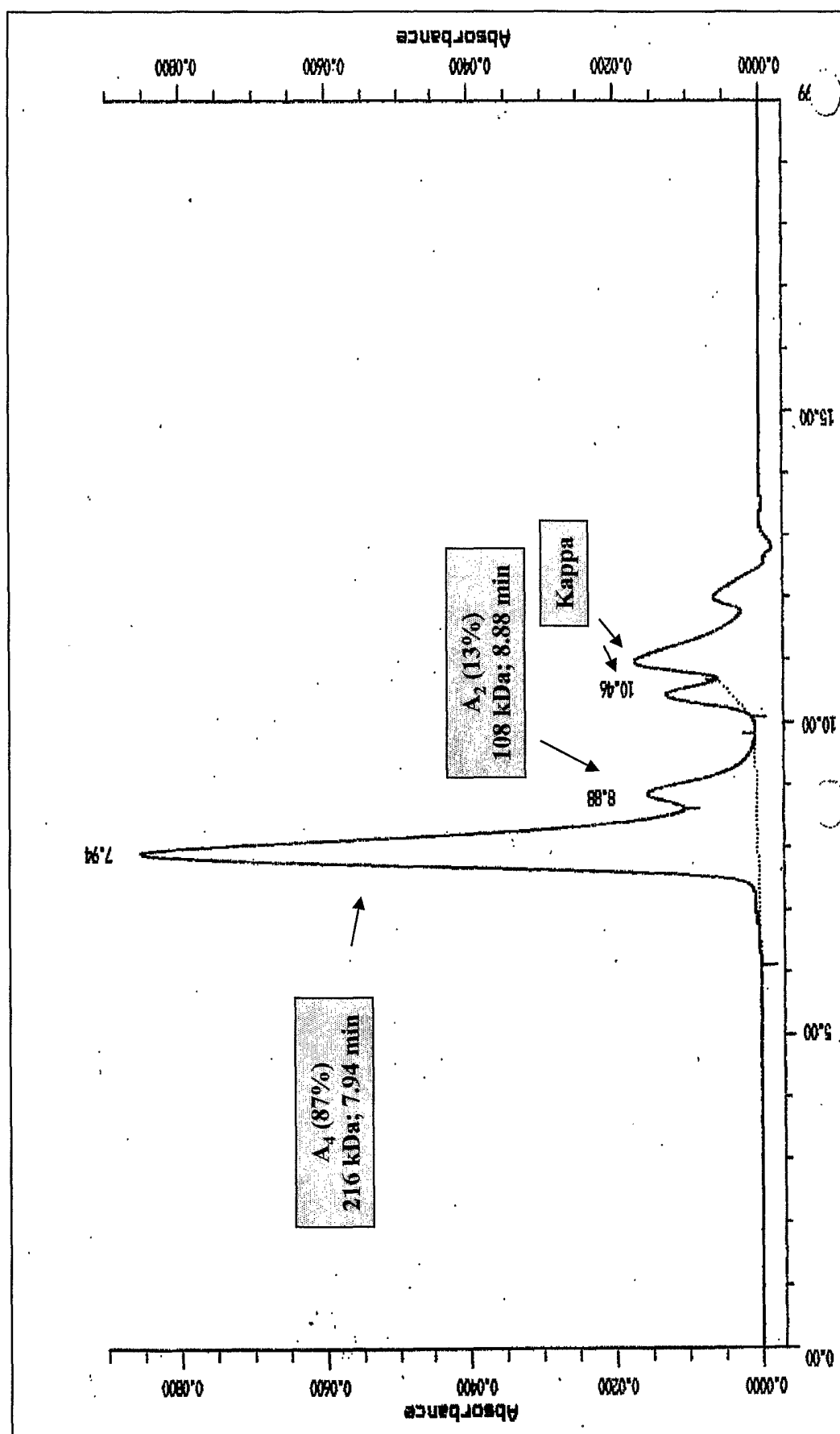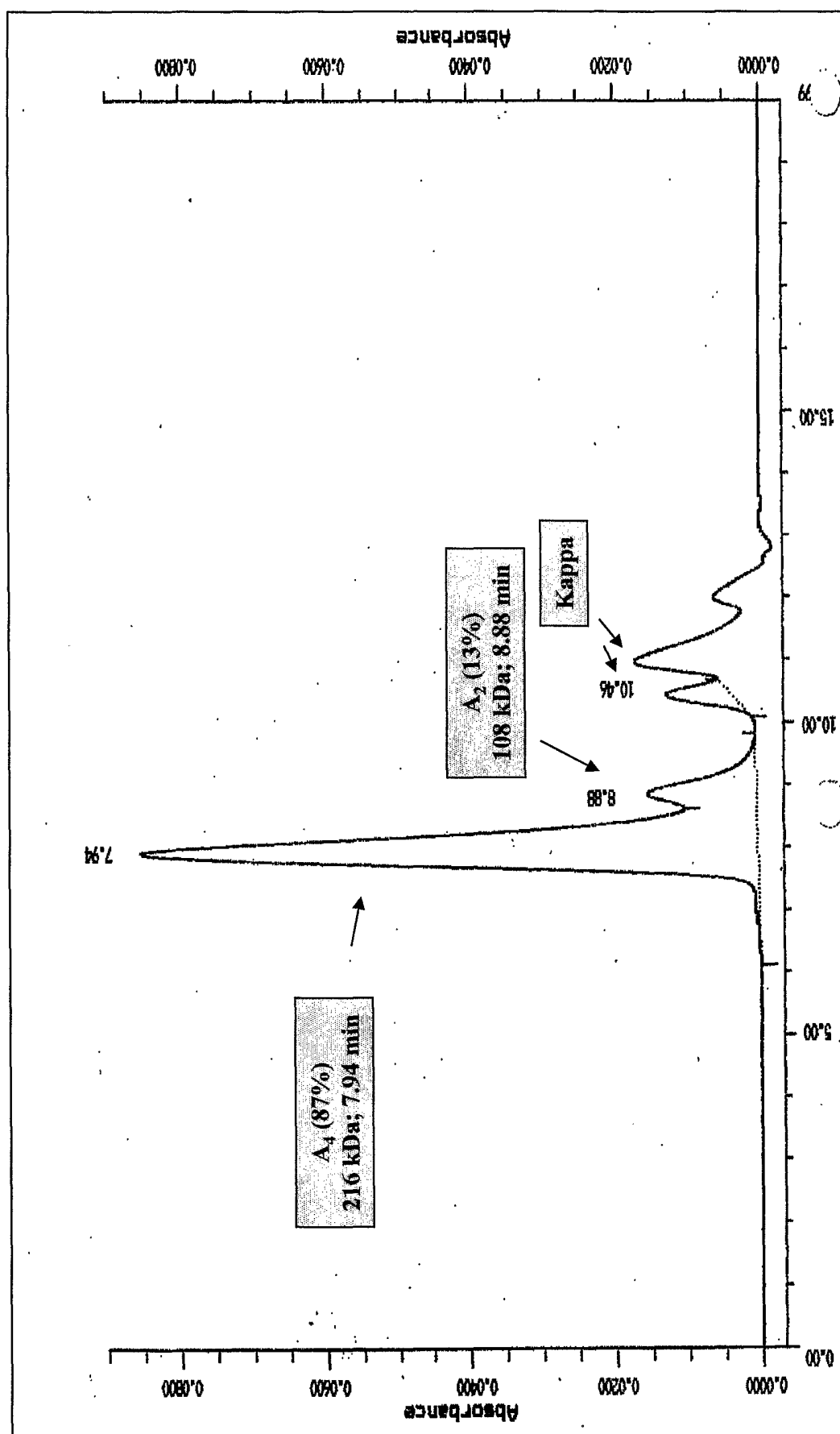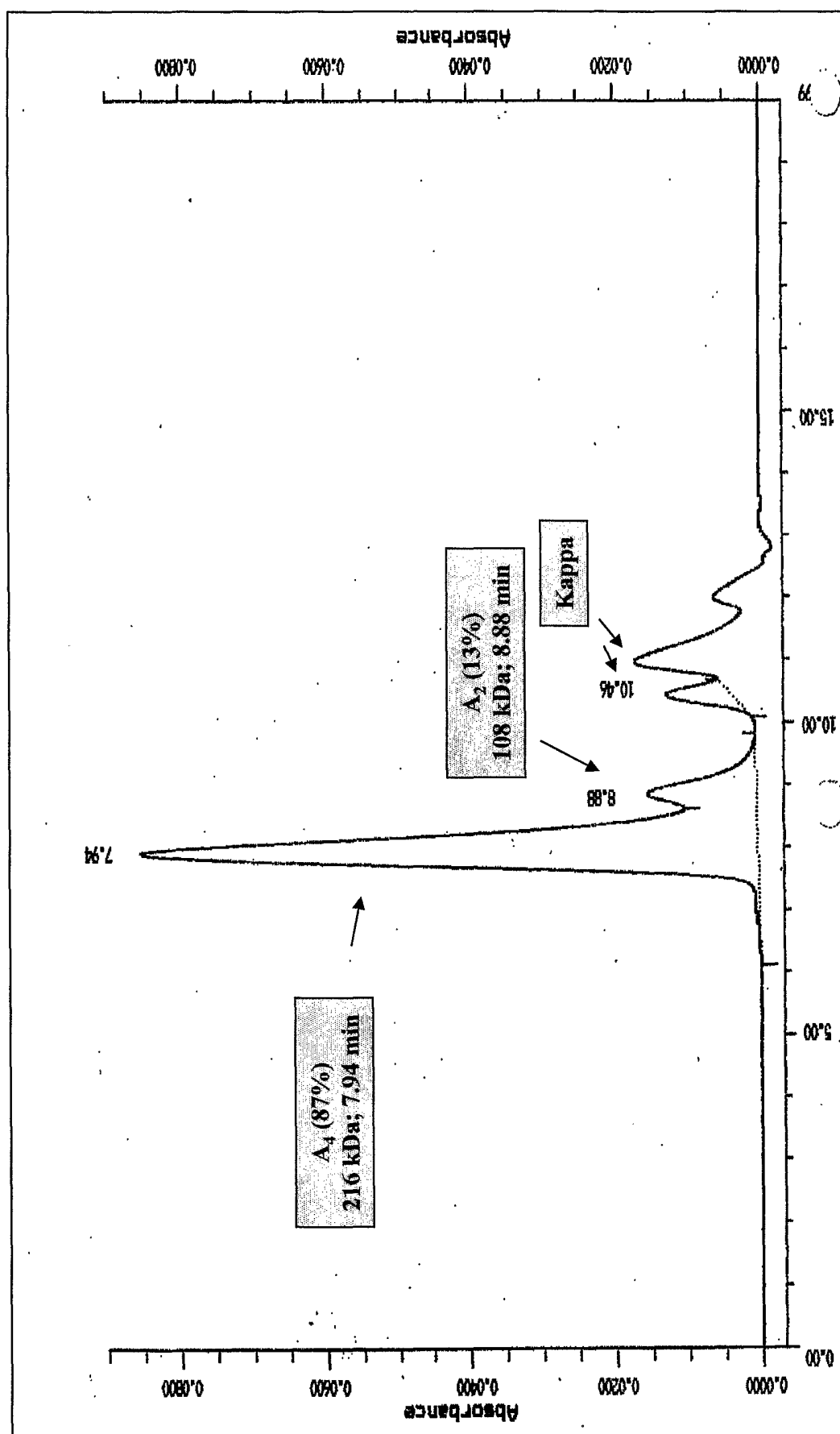
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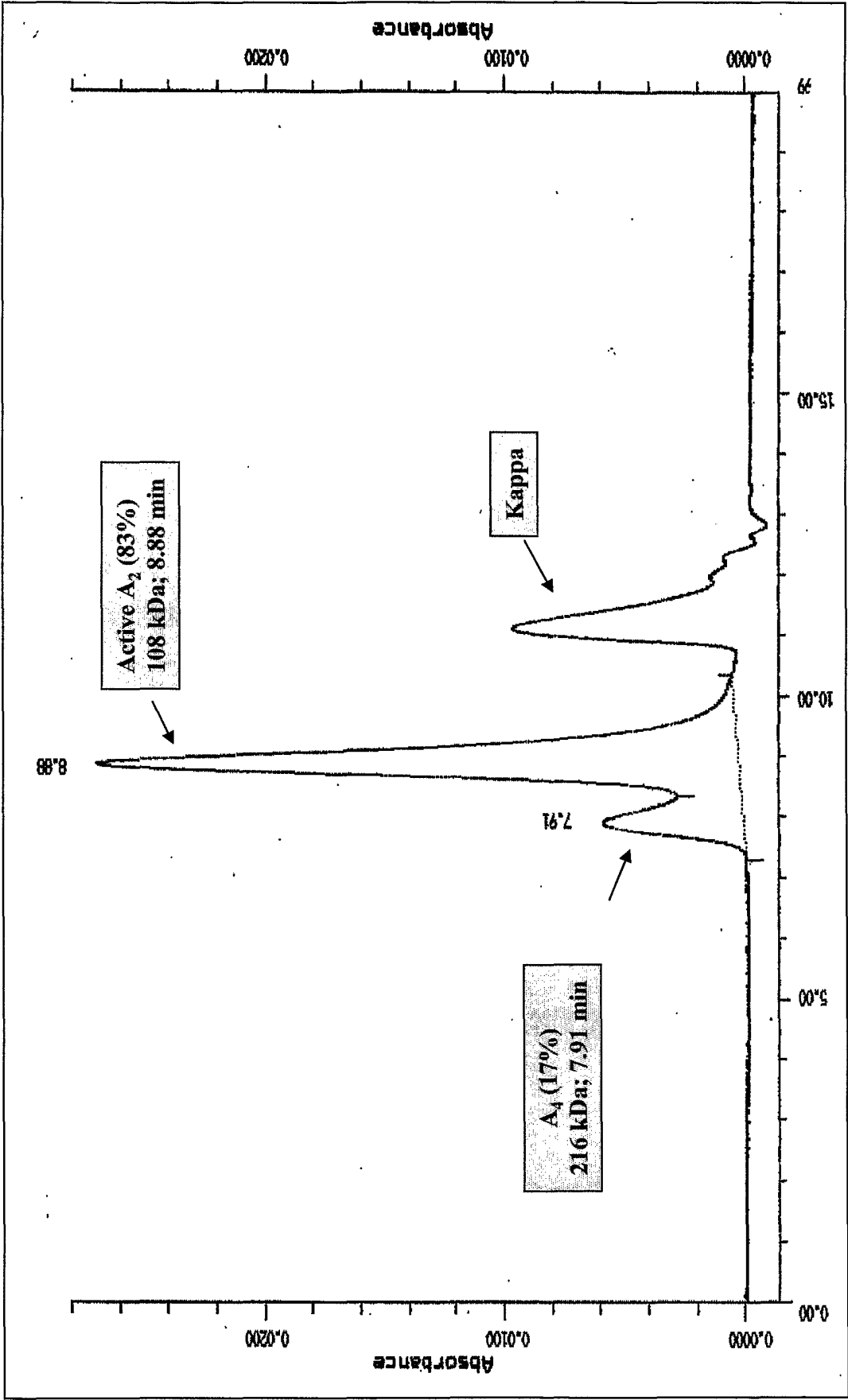
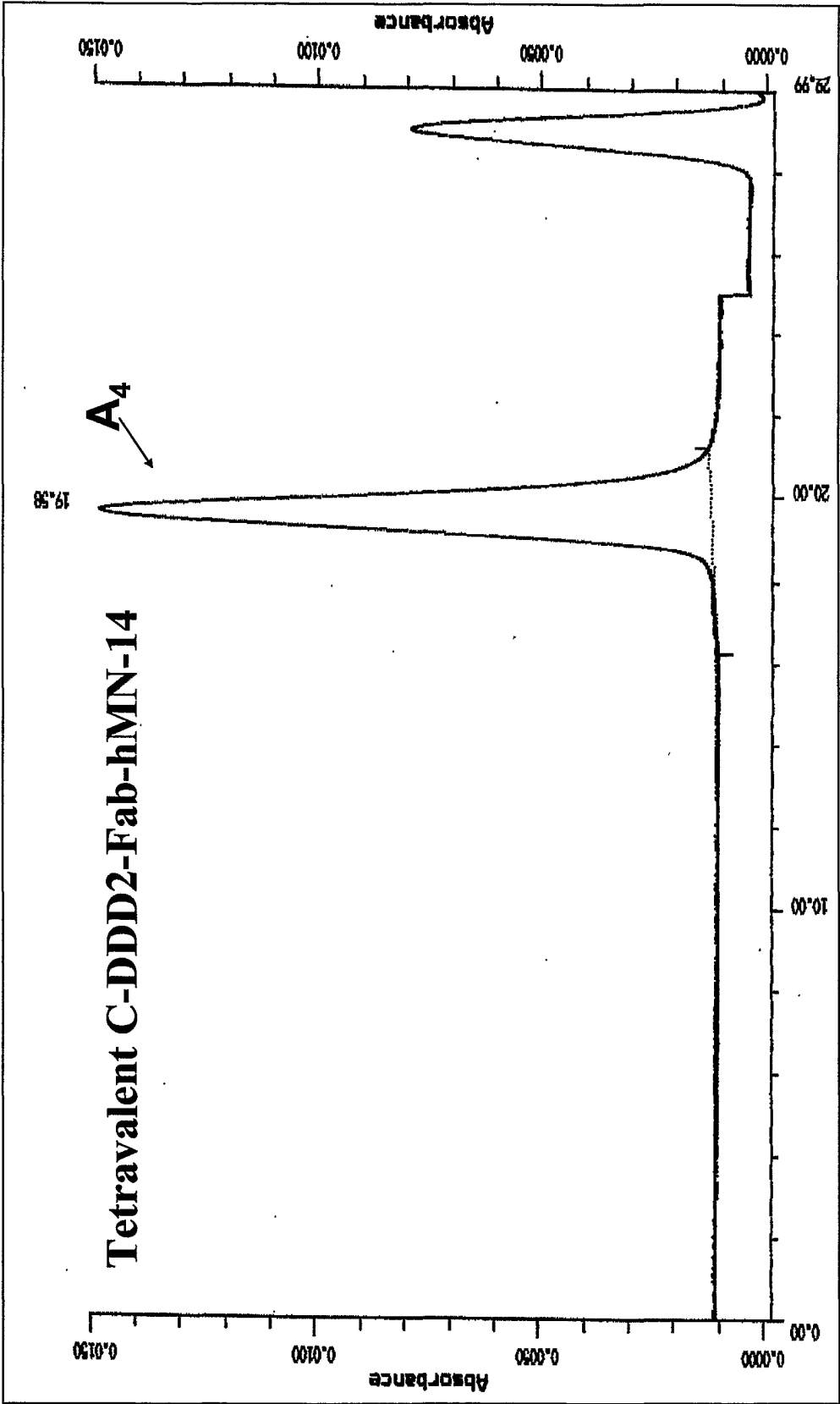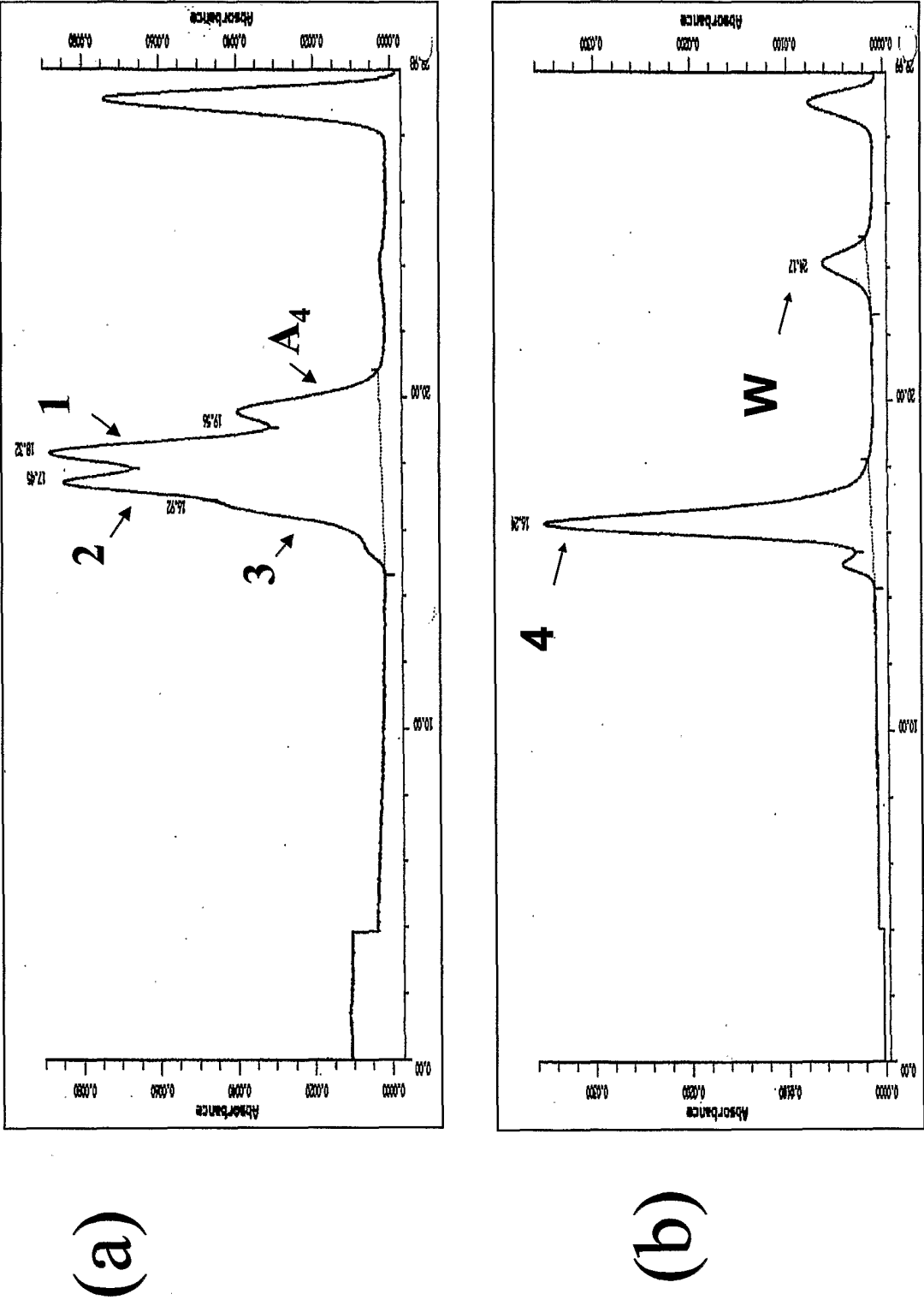Figure 19

Figure 20

Figure 21
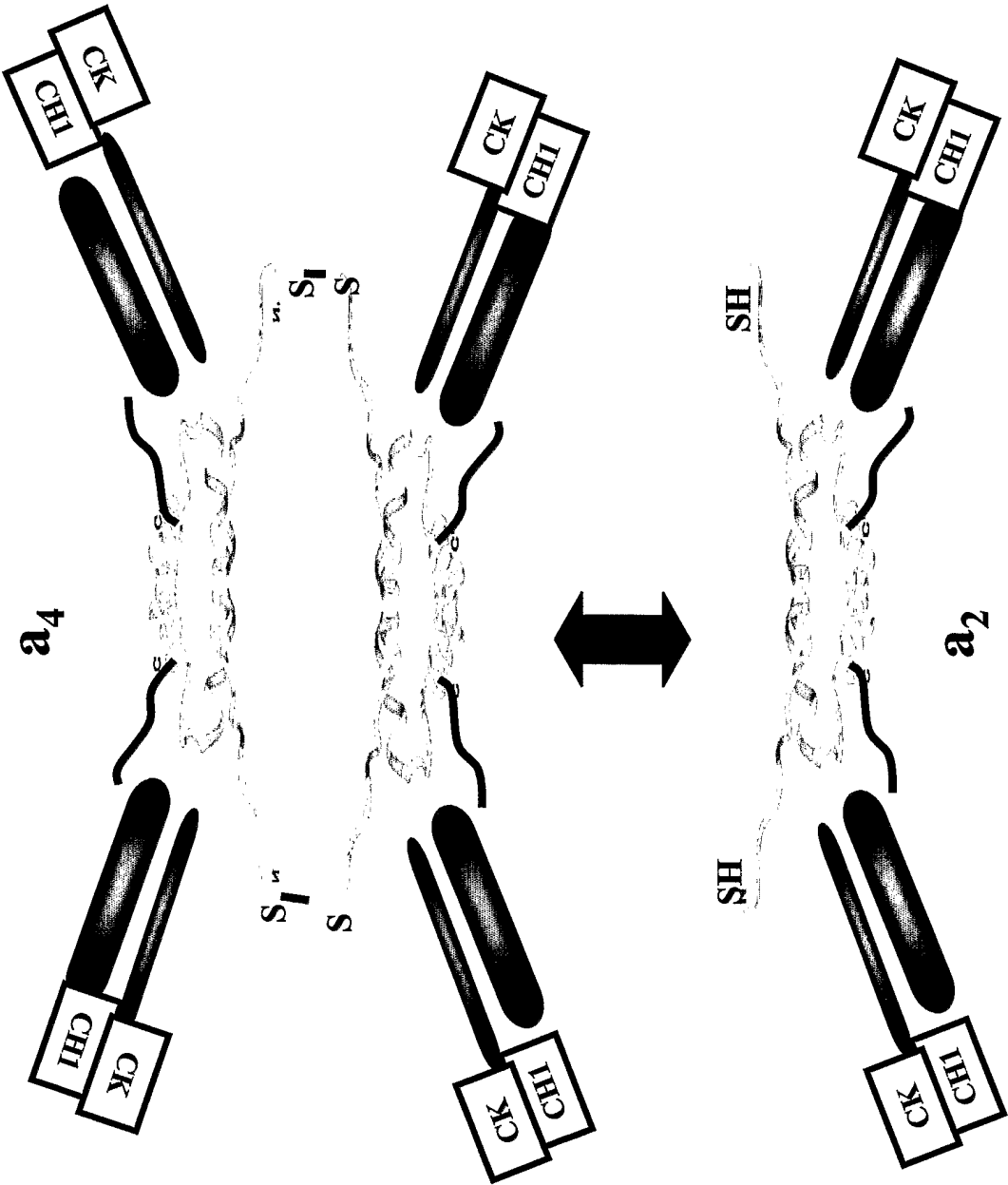
Figure 22

Figure 23

(a)

(b)

Figure 24

Tetravalent C-DDD2-Fab-hA20
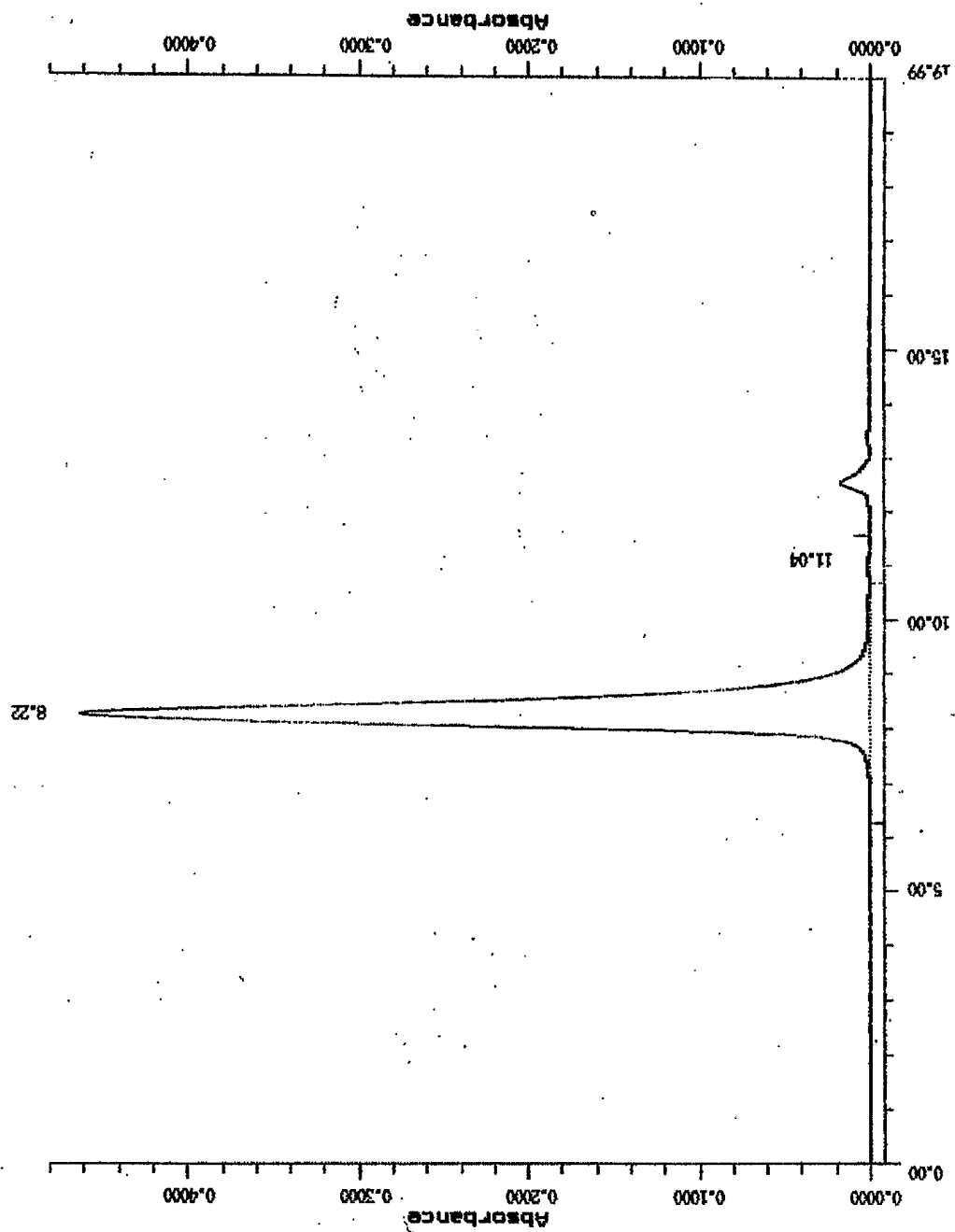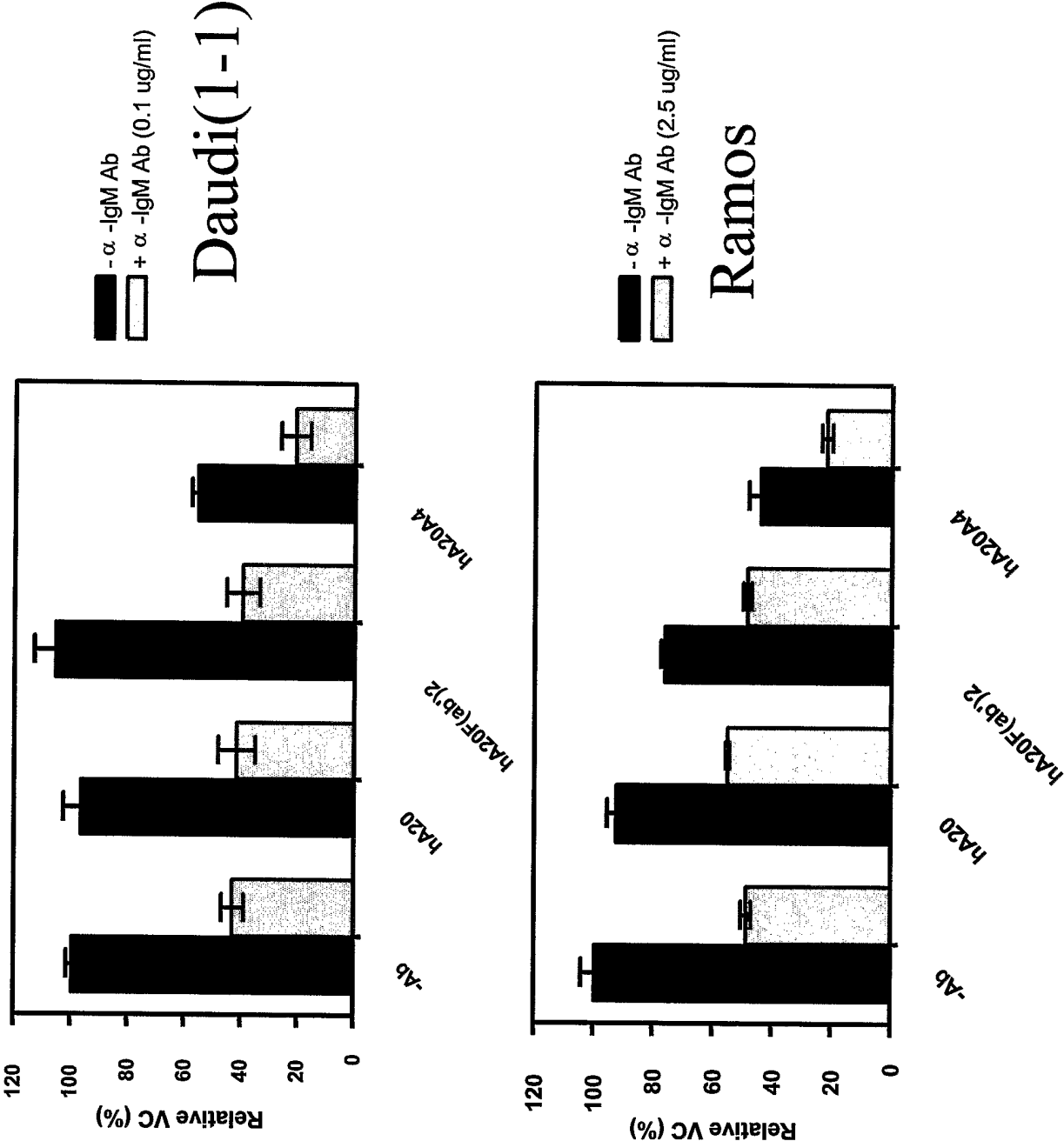
Figure 25

Figure 26

Bispecific assay for the presence of hMN-3xhA20
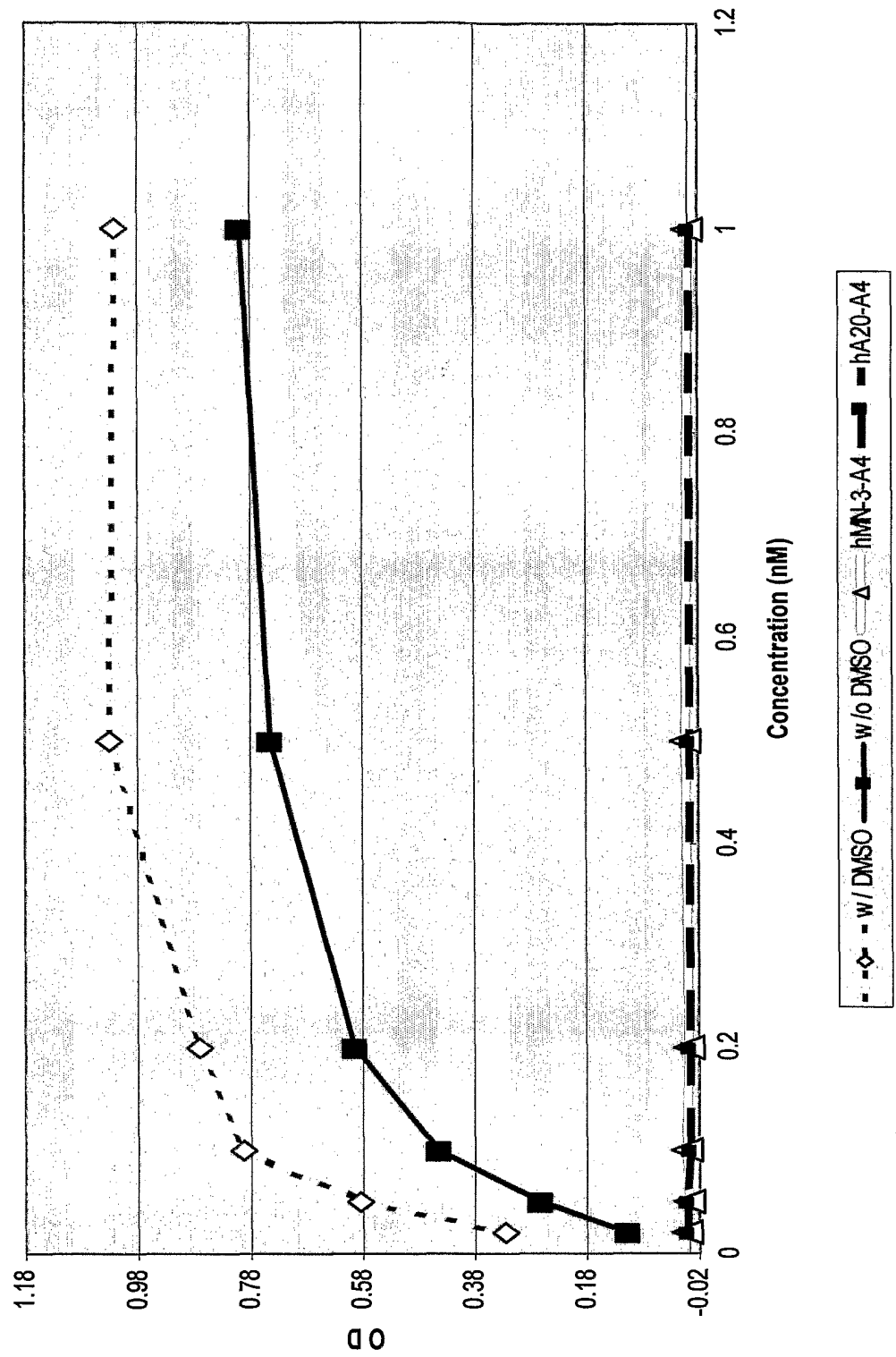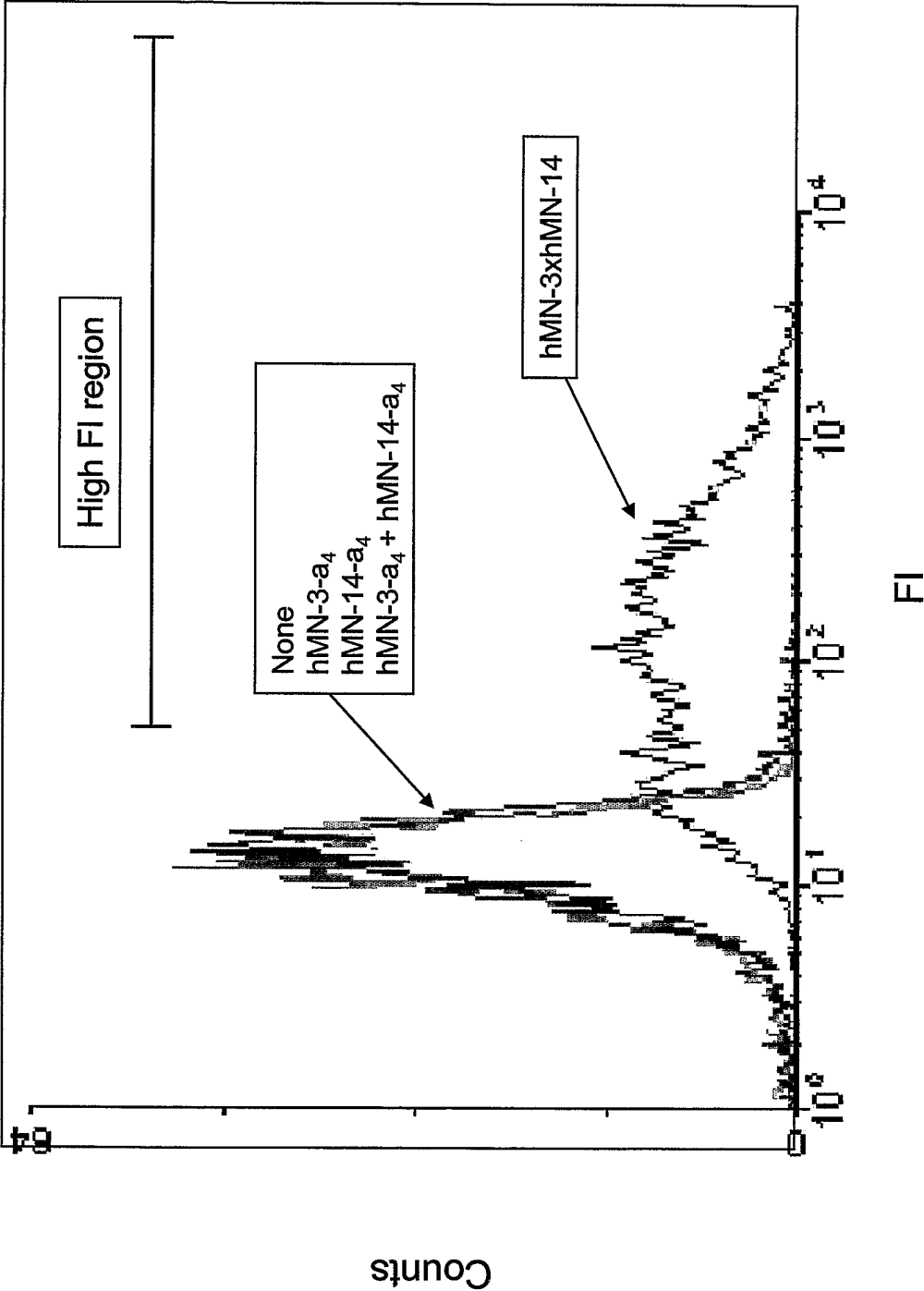Using CEA-coated plates

Figure 27

Bispecificity of hMN-3xhMN-14 (a_2a'_2 construct)

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       McBride, William J.
       Rossi, Edward A.

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