

**SYNTHESIS OF THERMO-MAGNETO-RESPONSIVE
POLY(N-ISOPROPYLACRYLAMIDE)-BASED COMPOSITE HYDROGELS
FOR ADSORPTION-DESORPTION OF CHROMIUM (III) IONS**

by

CHEN JIAN JIE

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LIST OF ABBREVIATIONS

AA	Acrylic acid
AAm-CA	Acrylamide-crotonic acid
AAS	Acrylic acid shell
AC	Activated carbon
AEM	Aminoethyl methacrylate hydrochloride
Ag ⁺	Silver (I) cation
APS	Ammonium persulfate
APTES	3-Aminopropyltriethoxysilane
AS-MNPs	Amino modified silica-iron oxide magnetic nanoparticles
Au	Gold
3-bt	3-butenic acid
Ca(OH) ₂	Lime (calcium hydroxide)
CCGO	Magnetic cyclodextrin-chitosan / graphene oxide
Cd ²⁺	Cadmium (II) cation
CEC	Cation exchange capacity
C ₂ H ₄ CONH	Acrylamide
C ₃ H ₈ NH	Pyrrolidine
C ₄ H ₁₀ NH	Piperidine
CM	Carboxymethylated
CM-β-CD-MNPs	Carboxymethyl-β-cyclodextrin (CM-β-CD) modified Fe ₃ O ₄ nanoparticles
Co ²⁺	Cobalt (II) cation
CO	Carbonyl group
CONH	Amide group
COO ⁻	Carboxylate group
COOH	Carboxylic group
Cr	Chromium
Cr ³⁺	Chromium (III) cation
Cr ⁶⁺	Chromium (VI) cation
CrCl ₃ ·6H ₂ O	Chromium (III) chloride hexahydrate

$\text{CrN}_3\text{O}_9 \cdot 9\text{H}_2\text{O}$	Chromium (III) nitrate nonahydrate
$\text{Cr}(\text{H}_2\text{O})_6^{3+}$	Hexaaquachromium (III) cation
$\text{Cr}(\text{OH})_4^{4-}$	Tetrahydroxochromate (III) anion
$\text{Cr}(\text{OH})_3$	Chromium (III) hydroxide
$\text{Cr}_2(\text{OH})_2^{4+}$	Binuclear dihydroxochromium (III) cation
$\text{Cr}_3(\text{OH})_4^{5+}$	Trinuclear tetrahydroxochromium (III) cation
CS	Chitosan
CS	Core-shell
Cs^+	Cesium (I) cation
CS-PAA	Chitosan-poly(acrylic acid)
CTAB	Cetyltrimethylammonium bromide
Cu^{2+}	Copper (II) cation
DBS	n-dodecylbenzenesulfonic
D_h	Hydrodynamic diameter
DLS	Dynamic light scattering
DNA	Deoxyribonucleic acid
ED	Electrodialysis
EDC·HCl	(3-dimethylaminopropyl) carbodiimide hydrochloride
EtOH	Ethanol
Eu^{3+}	Europium (III) cation
FAU	Faujasites
Fe^{2+}	Ferrous ion
Fe^{3+}	Ferric ion
$\text{Fe}(\text{acac})_3$	Ferric acetylacetonate
$\text{Fe}_2(\text{CrO}_4)_3$	Ferrous chromate
Fe_3O_4	Magnetite
$\gamma\text{-Fe}_2\text{O}_3$	Maghemite
FRP	Free radical polymerization
FT-IR	Fourier transform infrared spectroscopy
GLA	Glutaraldehyde
HAC	High adsorption capacities
HEMA	2-Hydroxyethyl methacrylate

HCl	Hydrochloric acid
HEC-g-PAA	Hydroxyethyl cellulose-g-poly(acrylic acid)
Hg ²⁺	Mercury (II) cation
H ₂ O	Water
IDA	Iminodiacetic acid
IEP	Isoelectric point
IPN	Inter-penetrating networks
KPS	Potassium persulfate
LCST	Lower critical solution temperature
LOD	Limit of detection
MBA	<i>N, N'</i> -methylene-bis-acrylamide
MgO	Magnesium Oxide
MC	Merocyanine
MNPs	Iron Oxide Magnetic Nanoparticles
MPS	3-(trimethoxysilyl)propyl methacrylate
MW	Molecular weight
MWCO	Molecular weight cut-off
NaNO ₃	Sodium nitrate
NaOH	Sodium hydroxide
Na ₂ SO ₄	Sodium sulfate
NF	Nanofiltration
Ni ²⁺	Nickel (II) cation
NIPAM	<i>N</i> -isopropylacrylamide
NH	Amine group
NHS	N-hydroxysuccinimide
OH	Hydroxyl group
PAA	Poly(acrylic acid)
PAAm-HAp	Polyacrylamide-hydroxyapatite
PAC / PEG	Polyacrylate / poly(ethylene glycol)
P(AMPS-co-GT)-GO	Poly[(2-acrylamido-2-methyl propanesulfonic acid)-co-gum tragacanth] grafted graphene oxide composite

P(AMPS-co-IA)	Poly[2-(acrylamido)-2-methyl-1-propanesulfonic acid-co-itaconic acid]
Pb ²⁺	Lead (II) cation
PEDOT / PSS	Lignin-poly(3,4-ethylenedioxythiophene) / polystyrene sulfonate
PEGDA	Poly(ethylene glycol) diacrylate
PNaAA	Poly(sodium acrylate)
PNIPAM	Poly(<i>N</i> -isopropylacrylamide)
PNIPAM-co-AA	Poly(<i>N</i> -isopropylacrylamide-co-acrylic acid)
(PNIPAM-co-AA)-silica-PVP-MNPs	Poly(<i>N</i> -isopropylacrylamide-co-acrylic acid)-gelated silica- poly(vinylpyrrolidone)-iron oxide magnetic nanoparticles composite hydrogel
PNIPAM-co-AAm-co-MA	Poly(<i>N</i> -isopropylacrylamide-co-acrylamide-co-maleic acid)
P(NIPAM-co-BCAm)	Poly(<i>N</i> -isopropylacrylamide-co-benzo-18-crown-6-acrylamide)
PNIPAM-silica-PVP-MNPs	Poly(<i>N</i> -isopropylacrylamide)-gelated silica-poly(vinylpyrrolidone)-iron oxide magnetic nanoparticles composite hydrogel
PSt	Polystyrene
P(St-NIPAM)	Poly(styrene- <i>N</i> -isopropylacrylamide)
PSt-PNIPAM	Polystyrene-poly(<i>N</i> -isopropylacrylamide)
PVP	Poly(vinylpyrrolidone)
P(4-VP-co-HEMA)	Poly(4-vinyl pyridine-co- 2-hydroxyethylmetacrylate)
SCH ₂ COOH	Thiodiglycolic acid
SDBS	Sodium n-dodecylbenzenesulfonate
SH	Sodium humate
silica	Silica coating layer
SiOH	Silanol
SiOSi	Siloxane
SO ₃ H	Sulfonic acid
SP	Spiropyran

SP-PNVCL	Spiropyran-ended poly(N-vinyl caprolactam)
Sr ²⁺	Strontium (II) cation
St	Starch
TEOS	Tetraethyl orthosilicate
Th ⁴⁺	Thorium (IV) cation
THF	Tetrahydrofuran
TS-SPE	Temperature-swing solid-phase extraction
U ⁶⁺	Uranium (VI) cation
UF	Ultrafiltration
UO ₂ ²⁺	Uranyl cation
UV	Ultraviolet
UV-Vis	Ultraviolet-visible
V50	2,2'-Azobis(2-amidinopropane) dihydrochloride
VIM	<i>n</i> -vinyl imidazole
VPT	Volume phase transition
VPTT	Volume phase transition temperature
Zn ²⁺	Zinc (II) cation

LIST OF SYMBOLS

T	Temperature (°C and K)
pK_a	Acid dissociation constant
pK_b	Base dissociation constant
D_h	Hydrodynamic diameter (nm)
ζ	Zeta potential (mV)
R	Cr ³⁺ removal percentage (%)
C_0	Initial concentration of copper (II) cations in solution (mg L ⁻¹)
C_e	Equilibrium concentration in solution (mg L ⁻¹)
M	Dry mass of adsorbent (g)
V	Total volume of solution (L)
q_e	Equilibrium adsorption capacity (mg g ⁻¹)
q_m	Maximum equilibrium adsorption capacity (mg g ⁻¹)
q_t	Equilibrium adsorption capacity at time t (mg g ⁻¹)
K_L	Langmuir constant (L mg ⁻¹)
R_L	Langmuir separation factor
K_F	Freundlich constant (L g ⁻¹)
$1/n$	Freundlich heterogeneity factor
B	Dubinin-Radushkevich constant related to adsorption energy (mol ² k ⁻¹ J ⁻²)
R	Gas constant (8.314 J mol ⁻¹ K ⁻¹)
ε	Polanyi potential

E	Free mean energy of the adsorption (kJ mol^{-1})
b	Temkin constant related to heat of adsorption (J mol^{-1})
K_T	Temkin constant (L g^{-1})
θ	Degree of surface coverage by adsorbates
K_{FH}	Flory-Huggins equilibrium constant (L g^{-1})
n	Flory-Huggins model exponent
ΔG°	Standard free energy change (kJ mol^{-1})
K_{FR}	Frumkin equilibrium constant (L g^{-1})
a	interaction parameter related to the interaction energy of the adsorbates
k_1	Pseudo-first-order rate constant (min^{-1})
k_2	Pseudo-second-order rate constant ($\text{g mg}^{-1} \text{min}^{-1}$)
k_{id}	Intra-particle diffusion rate constant ($\text{mg g}^{-1} \text{min}^{-1/2}$)
C_{id}	Constant related to the thickness of the boundary layer (mg g^{-1})