

Upconverting nanovesicles for the activation of ruthenium anti-cancer prodrugs with red light

Askes, S.H.C.

Citation

Askes, S. H. C. (2016, November 24). *Upconverting nanovesicles for the activation of ruthenium anti-cancer prodrugs with red light*. Retrieved from https://hdl.handle.net/1887/44378

Version: Not Applicable (or Unknown)

License: License agreement concerning inclusion of doctoral thesis in the

Institutional Repository of the University of Leiden

Downloaded from: https://hdl.handle.net/1887/44378

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle http://hdl.handle.net/1887/44378 holds various files of this Leiden University dissertation.

Author: Askes, S.H.C.

Title: Converting nanovesicles for the activation of ruthenium anti-cancer prodrugs with

red light **Issue Date:** 2016-11-24

UPCONVERTING NANOVESICLES FOR THE ACTIVATION OF RUTHENIUM ANTI-CANCER PRODRUGS WITH RED LIGHT

PROEFSCHRIFT

Ter verkrijging van

de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus Prof. mr. C. J. J. M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op donderdag 24 november 2016
klokke 10:00 uur

Sven Holger Christiaan Askes geboren te Culemborg, Nederland, 1989

Samenstelling Promotiecommissie

Promotor

Prof. dr. E. Bouwman

Copromotor

Dr. S. Bonnet

Overige Leden

Prof. dr. J. Brouwer

Prof. dr. A. Kros

Prof. dr. S. Baluschev

Verbonden aan Sofia University "St. Kliment Ochridski" (Bulgarije) en Max Planck Institute for Polymer Research (Mainz, Germany)

Dr. F. C. Grozema

Verbonden aan Technische Universiteit Delft

Dr. L. Salassa

Verbonden aan Centre for Cooperative Research in Biomaterials "CIC biomaGUNE" (San Sebastián, Spain)

This work has been financially supported by Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).

Printing was financially supported by Avantes BV.

"Just remember, you can't climb the ladder of success with your hands in your pockets"

Arnold Schwarzenegger

"Those worlds in space are as countless as all the grains of sand on all the beaches of the Earth. Each of those worlds is as real as ours. In every one of them, there's a succession of incidences, events, occurrences which influence its future. Countless worlds, numberless moments, an immensity of space and time. And our small planet, at this moment, here we face a critical branch-point in the history. What we do with our world, right now, will propagate down through the centuries and powerfully affect the destiny of our descendants. It is well within our power to destroy our civilization, and perhaps our species as well. If we capitulate to superstition, or greed, or stupidity we can plunge our world into a darkness deeper than the time between the collapse of classical civilization and the Italian Renaissance. But we are also capable of using our compassion and our intelligence, our technology and our wealth to make an abundant and meaningful life for every inhabitant of this planet. To enhance enormously our understanding of the Universe, and to carry us to the stars."

Carl Sagan

Dedicated to all great minds of past and present, on whose shoulders we may stand.

Table of Contents

Chapter 1	7
Introduction I: Ruthenium polypyridyl complexes as potential anticancer prodrugs in photoactivated chemotherapy	
Chapter 2	21
Introduction II: Light upconversion using triplet-triplet annihilation	
Chapter 3	43
Activation of a photodissociative ruthenium complex by triplet-triplet annihilation upconversion in liposomes	
Chapter 4	59
Triplet-triplet annihilation upconversion followed by FRET for the red light activation of a photodissociative ruthenium complex in liposomes	
Chapter 5	81
Imaging the lipid bilayer of giant unilamellar vesicles using red-to-blue light upconversion	
Chapter 6	95
Temperature dependence of triplet-triplet annihilation upconversion in phospholipid membranes	
Chapter 7	109
Synthesis and in-vitro application of upconverting silica-coated liposomes	
Chapter 8	135
Activation of liposome-bound Ru(II) prodrugs using red-to-blue triplet-triplet annihilation upconversion in a biological context	

Chapter 9	179
Imaging upconverting polymersomes in cancer cells: biocompatible antioxidants brighten triplet-triplet annihilation upconversion	
Chapter 10	203
Summary, conclusions, and outlook	
Appendix I : Determination of quantum yield of upconversion	215
Appendix II : Supporting information for Chapter 3	221
Appendix III : Supporting information for Chapter 4	223
Appendix IV : Supporting information for Chapter 5	245
Appendix V : Supporting information for Chapter 6	251
Appendix VI : Supporting information for Chapter 7	253
Appendix VII : Supporting information for Chapter 8	257
Appendix VIII : Supporting information for Chapter 9	267
Samenvatting in het Nederlands	285
Curriculum Vitae	293
List of publications	295
Acknowledgements	297