Incoherent Light Sources

M. Sc. Chemical Engineering / Photonics

September 24th, 2018

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Name: _____

Enrolment number: _____

Day of Birth: _____

Please keep in mind to clearly figure out the solution approach and the results. Please solely use IUPAC units.

Duration 180 Minutes

Allowed aids: Periodic table of the elements, pocket calculator, Dieke diagram, formulaic collection math

Points	
Task 1:	10 Points
Task 2:	10 Points
Task 3:	10 Points
Task 4:	10 Points
Task 5:	10 Points
Task 6:	10 Points
Task 7:	10 Points
Task 8:	10 Points
Task 9:	10 Points
Task 10:	10 Points

Mark	
1.0	95 – 100 Points
1.3	90 – 94 Points
1.7	85 – 89 Points
2.0	80 – 84 Points
2.3	75 – 79 Points
2.7	70 – 74 Points
3.0	65 – 69 Points
3.3	60 – 64 Points
3.7	55 – 59 Points
4.0	50 – 54 Points
5.0	0 – 49 Points

Success!

Task 1 **(10 Points)**

Physical Basis of Light Generation

a) Please describe three kind of physical processes, which are applied in electrical light sources. Please also figure out the light generation pathway! (6 Points)

b) Please explain the expression „Thermoluminescence“! In which historical light source is such process of importance? (2 Points)

c) Please explain the expression „Cathodoluminescence! In which technical devices is such process of importance? (2 Points)

Task 2 **(10 Points)**

Terms from Lighting Technology

a) Please explain the following lighting terms! (0.5 Points each)

- Radiant flux
- Luminous flux
- Color point
- Color temperature
- Color rendering index

b) The term energy efficiency ε means the conversion of electrical input power P_{el} to optical output power P_{opt}. The term luminous efficacy ε_v describes the relation between the luminous flux Φ_v and the radiant flux Φ_e. (Please complete the following table! 0.5 Points each)

Light source	**Electrical input power P_{el}**	**Energy efficiency ε**	**Radiant flux Φ_e**	**Luminous efficacy ε_v [lm/$W_{optical}$]**	**Luminous flux Φ_v**	**Light yield [lm/$W_{el.}$]**
Halogen lamp	100 W	10%		250		
Low-pressure Na discharge lamp	200 W	40%		500		
Low-pressure Hg discharge lamp (fluorescent lamp)	36 W	30%		300		
Cool-white LED	5 W	80%		350		
Warm-white LED	5 W	40%		280		

Task 3 **(10 Points)**

Incandescence and Halogen Lamps

a) Sketch the spectrum of an incandescent lamp and compare it to the extra-terrestrial solar spectrum! (3 Points)

b) What chemical transport reactions do occur in halogen and incandescent lamps? (3 Points)

c) Calculate the wavelengths at which the emission of a black body is maximal for 3000 and 6000 K using Wien's displacement law! (2 Points)

(Wien's displacement law: $\lambda_{max} = 2880 / T$ [µm*K])

d) Name two technical measures to increase the lifetime of an incandescent lamp? (2 Points)

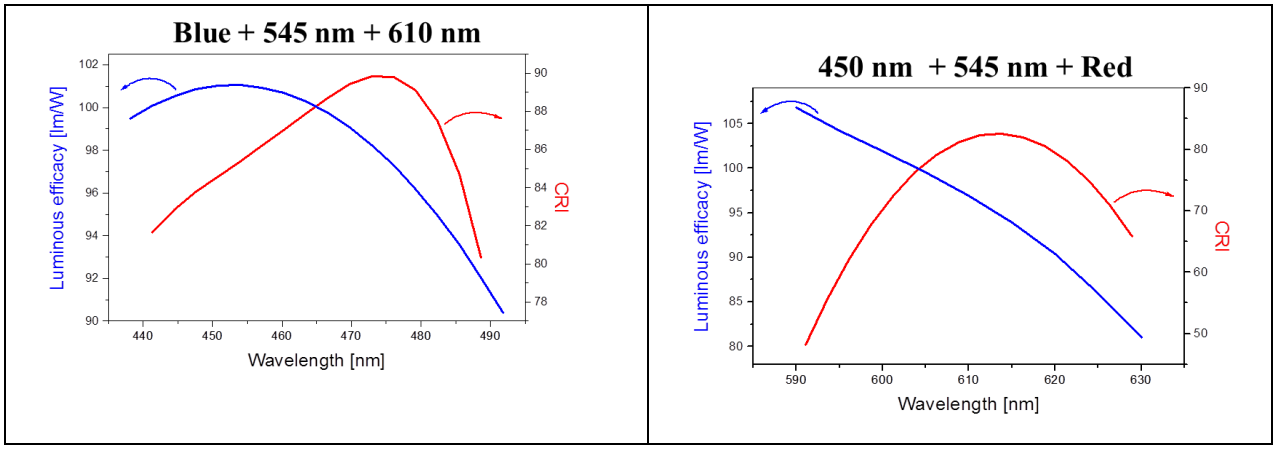
Task 4 **(10 Points)**

Low-Pressure Discharge Lamps

a) Name two chemical elements which are often applied as discharge component in low-pressure discharge lamps! Please explain your choice! (2 Points)

b) Please sketch the light generation chain in a tubular fluorescent lamp! (4 Points)

c) The following graphs show the luminous efficacy and CRI values of a trichromatic fluorescent lamp. Please name the consequences for the choice of the blue and red emitting component with respect to the light yield and CRI of such lamps? (2 Points)



d) Name two activator ions, which are used in luminescent materials for low-pressure Hg discharge lamps and explain your choice! (2 Points)

Task 5 **(10 Points)**

High-Pressure Discharge Lamps

a) Please explain the origin of the spectral shift of a low-pressure Hg discharge with increasing pressure? (3 Points)

b) Calculate the energy efficiency ε of a Hg high-pressure lamp using YVO_4:Eu as a phosphor taking into consideration the following data: discharge efficiency = 40% with 30% visible emission, 10% UV emission at 365 nm, which is completely converted to line emission of YVO_4:Eu at 615 nm, quantum efficiency of the phosphor at λ_{365} = 90%! (4 Points)

c) Please name two application areas of high-pressure lamps and explain the advantage of such lamps over low-pressure lamps! (3 Points)

Task 6 **(10 Points)**

Luminescence Mechanisms

a) Please explain the term quenching and give an example! (2 Points)

b) Please explain the term sensitisation with a self-imposed example! (2 Points)

c) Please argue the importance of lanthanide ions as activators in many phosphors! (2 Points)

d) Please mention a way to sensitise the following rare earth ions! (4 Points)

a) Nd^{3+}
b) Eu^{3+}
c) Tb^{3+}
d) Yb^{3+}

Task 7 **(10 Points)**

Inorganic Luminescent Materials

a) Which activators ions are suitable for the following emission ranges? (6 Points)

- UV-C
- UV-B
- UV-A
- Blue
- Green
- NIR

b) Please explain the impact of lattice defects on the performance and properties of inorganic luminescent materials! (2 Points)

c) What is an afterglow pigment? Give an example and argue your choice! (2 Points)

Task 8 **(10 Points)**

Inorganic Light Emitting Diodes (ILEDs)

a) $(Ga_{1-x}In_x)N$ and $(Ga_{1-x}In_x)P$ are important solid solutions for semiconductor LEDs. Please sketch the course of the band gap as function of x for these nitrides and phosphides. Please also compare the two solid solutions with each other! (3 Points)

b) Explain the success of III-V semiconductor LEDs with respect to lifetime, temperature resistance, spectral consistency, and efficacy! (4 Points)

c) Please mention three processes, which govern the wall plug efficiency of an inorganic LED! (3 Points)

Task 9 **(10 Points)**

Organic Light Emitting Diodes (OLEDs)

a) Describe the process of manufacturing of OLEDs and PLEDs. Please also explain the causes for the different manufacturing processes! (3 Points)

b) Explain the causes for the dominance of Ir^{3+} complexes in OLEDs? (3 Points)

c) Explain the light generation chain in an OLED! (4 Points)

Task 10 **(10 Points)**

UV Radiation Sources

a) Please name four types of UV radiation sources (4 Points)

b) Please name three technically relevant photochemical reactions and propose a suitable UV radiation source! (3 Points)

c) Calculate the wall-plug efficiency ε of an UV radiation source based on a Hg low pressure discharge (discharge efficiency $\varepsilon_{discharge}$ = 70%, 15% 185 nm and 85% 254 nm), high frequency driver (ε_{driver} = 90%), and an UV-B phosphor (La,Bi)B_3O_6:Gd, 311 nm, QE = 90%)! (3 Points)

Appendix: Simplified Dieke Diagram for Ln^{3+} Ions