Problem Solving Class: Van Quark tot Biomaterie

Problem Set 1: Light Quanta Hand-in on paper Thursday 4 September (before 9:00 uur) Hand-in digitally, email to: <u>m.t.talluri@vu.nl</u> All documents in a single file [filename: YourName-WC-Q1] All answers in English

1) Planck curve

From the Planck curve peaking at ~ 500 nm the temperature of the Sun can be derived (see Example 37-1).

a) The Earth emits radiation (of importance for a process known as "global warming"). At what wavelength is this emission peak for Earth, assuming an average surface temperature of 290 K? Why would this lead to warming of the atmosphere ?

b) Argue why the classical Rayleigh-Jeans law is not consistent with a Wien displacement law, represented by $f_{\text{max}} \propto T$, or $\lambda_{\text{max}}T$ = constant.

c) The wavelength for maximum intensity λ_{max} can be obtained by setting the derivative in Planck's law (defined for wavelength) to zero:

$$\frac{dI_T}{d\lambda} = 0$$

Why does the optimum in the frequency domain representation not correspond to: $f_{\max}\lambda_{\max}=c$? Calculate f_{\max} in the proper manner.

2) Temperature of a radiant body

Find the temperature of a radiant body that emits a radiant density at 200 nm that is 3.82 times the density at 400 nm.

3) Photo-electric effect

Photons of energy 15 eV can ionize hydrogen atoms, since the ionization potential of hydrogen atoms is 13.5984 eV.

a) How many photons (of this energy 15 eV) are there in a (pulse of a) nanoJoule of radiation ?b) What is the *velocity* of the electrons liberated after photons of 15 eV are absorbed by gas of hydrogen atoms.

4) Compton effect

a) For what scattering angle is the change in wavelength maximal ?

b) Determine the ratio $(\Delta \lambda / \lambda)$ of the maximum change $\Delta \lambda$ in a photon's wavelength, if the photon

a (I) visible light with λ =550 nm, or (II) an X-ray photon with λ =0.10 nm.

So this explains why the Compton effect is best visible at very short wavelengths.