HALE SCHOOL
PHYSICS
Electromagnetic Radiation
YEAR 12 Unit 3B
Test 2012

Test Score:

Name: FIRST DRAFT   Set:

Teacher: JAA   MV

INSTRUCTIONS:

- ☐ Time Allowed = 40 minutes
- ☐ Total Marks = 40 marks
- ☐ Answer all questions in the space provided.
- ☐ Rough working is permitted on the question paper.
- ☐ Show all relevant working details in order to acquire full marks.
- ☐ Graphic Calculators are Not permitted for this paper.
- ☐ ***Do Not write in pencil. (Note: a 1 mark penalty will be incurred)**
- ☐ ***Do Not borrow materials. (Note: a 1 mark penalty will be incurred)**

POST ASSESSMENT REVIEW (to be completed upon return of your marked paper)

SELF-ASSESSMENT:

Relative Weaknesses –Objective No.

Relative Strengths –Objective No.

Major Concerns: (be specific)

Action Plan: (be specific)

Q1 [4 marks] TEE 1999

A laser beam used in surgery delivers 100 W of power to some tissue. If the laser emits red light of wavelength 680 nm calculate the number of photons hitting the tissue each second.

$E = hf = h\frac{c}{\lambda}$

$= \frac{6.62 \times 10^{-34} \times 3.00 \times 10^{8}}{680 \times 10^{-9}}$

$\therefore E = 2.925 \times 10^{-19}$ J EACH PHOTON

$\therefore$ N°/ PHOTONS $= \frac{100 \text{ J s}^{-1}}{2.925 \times 10^{-19}}$

$\therefore$ N°/ PHOTONS $= 3.42 \times 10^{20} \text{ s}^{-1}$

(4 marks)

Q2 [4 marks] TEE 1996

The claim made by a washing powder manufacturer is that their product contains "optical brighteners" to make clothes "whiter and brighter".

Identify the phenomenon responsible and carefully explain how these "whiteners" work.

THE WHITENERS ARE FLUORESCENT.
THEY ABSORB UV LIGHT FROM INCIDENT LIGHT
AND THE SUBSEQUENT TRANSITIONS OF
EXCITED ELECTRONS RETURNING TO THE
GROUND STATE, PRODUCE PHOTONS OF
(LOWER) VISIBLE FREQUENCIES.

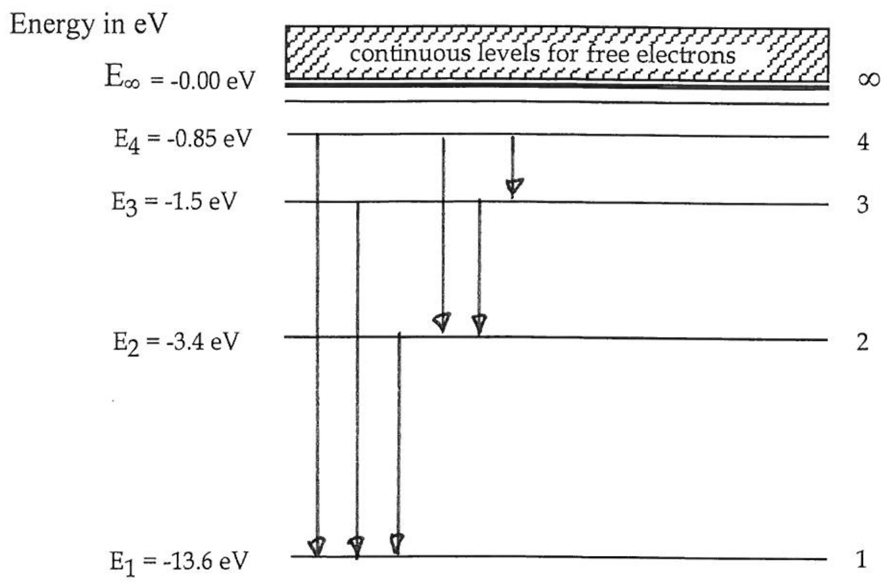
MORE VISIBLE PHOTONS ⇒ MORE INTENSE
⇒ MORE VISIBLE
⇒ "BRIGHTER"

THE INCREASE IN BLUE INTENSITY OF EMITTED PHOTONS MAKES THE CLOTHING "WHITER" OR LESS YELLOW

(4marks)

Q3 [14 marks]

An atomic energy level diagram for hydrogen is shown.



Energy level diagram for hydrogen

(2marks)

3a) An electron in the ground state is excited to the E4 energy level when it absorbs a photon. On the diagram above, draw the possible downward transitions for the electron.

3b) What might happen if a hydrogen atom in the ground state is struck by a photon with the following energies? Briefly explain your answers.

Photon Energy	Observations and Explanations
15.2 eV	THE ATOM MAY BE IONISED THE PHOTON HAS SUFFICIENT ENERGY (> 13.6 eV) TO EJECT AN ELECTRON FROM THE ATOM.
10.2 eV	AN ELECTRON MAY BE EXCITED FROM $E_1 \rightarrow E_2$ DIFFERENCE BETWEEN ENERGY LEVELS IS EXACTLY 10.2 eV (PHOTONS CAN NOT BE PARTIALLY ABSORBED)
2.90 eV	INSUFFICIENT ENERGY TO EXCITE ELECTRON FROM GROUND STATE PHOTON ENERGY MUST BE EQUIVALENT TO ENERGY TRANSITION. PHOTON IS REFLECTED RATHER THAN ABSORBED.

(6marks)

3c) An electron of energy 12.2 eV now collides with the hydrogen atom that is in its ground state. Determine the possible energies of the electron after collision.

UNLIKE PHOTONS, THE ENERGY MAY BE PARTIALLY ABSORBED

I) PERFECTLY ELASTIC COLLISION => 12.2 eV (NONE ABSORBED)

II) ATOM ABSORBES 10.2eV => 2.0 eV REMAINING WITH e^-

(12.2 − 10.2 = 2.0 eV)

III) ATOM ABSORBES 12.1 eV => 0.1 eV REMAINING WITH e^-

(12.2 − 12.1 = 0.1 eV)

(3 marks)

3d) Calculate the shortest wavelength emission of electromagnetic radiation resulting from such collisions.

THE SHORTEST WAVELENGTH PHOTON POSSESSES THE HIGHEST ENERGY TRANSITION POSSIBLE WHEN ATOM EMITS ABSORBED ENERG

$\Delta E = E_{3\to 1} = h\,c/\lambda$

$\therefore \lambda = \frac{hc}{\Delta E}$

$= \frac{6.62 \times 10^{-34} \times 3.00 \times 10^{8}}{(13.6 - 1.5) \times 1.6 \times 10^{-19}}$

$\therefore \lambda_{min} = 1.02 \times 10^{-7}$ m

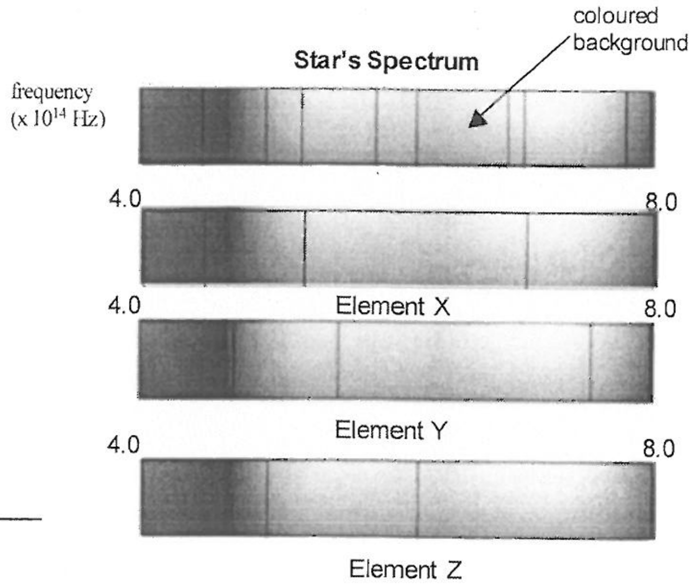
$= 102$ nm

(3 marks)

Q4 [8 marks]

Light from a distant star was collected by a telescope and analysed using a spectrometer.

The spectrum of the star's light together with the spectra of elements X, Y and Z are shown.



4a) What type of spectrum did the astronomers observe?

LINE ABSORPTION SPECTRA

(1 mark)

4b) Carefully explain the occurrence of the dark lines observed in the star's spectrum.

THE DARK LINES CORRESPOND TO THE SPECIFIC FREQUENCY/QUANTA PHOTONS THAT ARE ABSORBED AS THE LIGHT PASSES THROUGH THE STAR'S ATMOSPHERE. THE LINES REVEAL SPECIFIC ENERGY TRANSITIONS WHICH ARE POSSIBLE AND REFERENCED TO SPECIFIC ELEMENTS. (2 marks)

4c) How does the spectrum from a gas discharge tube containing element X, Y or Z differ in appearance from the star's spectrum? Briefly explain.

THE DISCHARGE TUBE PRODUCES AN EMISSION SPECTRUM FOR THE ELEMENTS. THE SPECTRA APPEAR AS DISCRETE BRIGHT COLOURED LINES ON A DARK/BLACK BACKGROUND. THE DISCRETE LINES RESULT FROM THE DOWNWARD TRANSITION OF ELECTRONS FROM EXCITED ENERGY STATES. (MOST) COLOURED LINES CORRESPOND TO THE DARK LINES OF THE ABSORPTION SPECTRA AND CAN THEREBY BE REFERENCED FOR ANALYSIS

(3 marks)

4d) Which of the elements X, Y and Z are likely to occur in the star? Briefly justify your answer.

X AND Z ARE LIKELY PRESENT IN THE STAR'S ATMOSPHERE. THE DISCRETE LINES ASSOCIATED WITH EACH ELEMENT (X AND Z) ARE PRESENT IN THE STAR'S ABSORPTION SPECTRUM, WHEREAS Y'S LINES ARE ABSENT.

(2 marks)

Q5 [5 marks]

Some students are investigating the photoelectric effect. They shine light of different wavelengths onto a rubidium plate. They measure the maximum kinetic energy of photoelectrons emitted from the plate. Their data of maximum kinetic energy of ejected photoelectrons as a function of the frequency of incident light is shown in Figure 1.

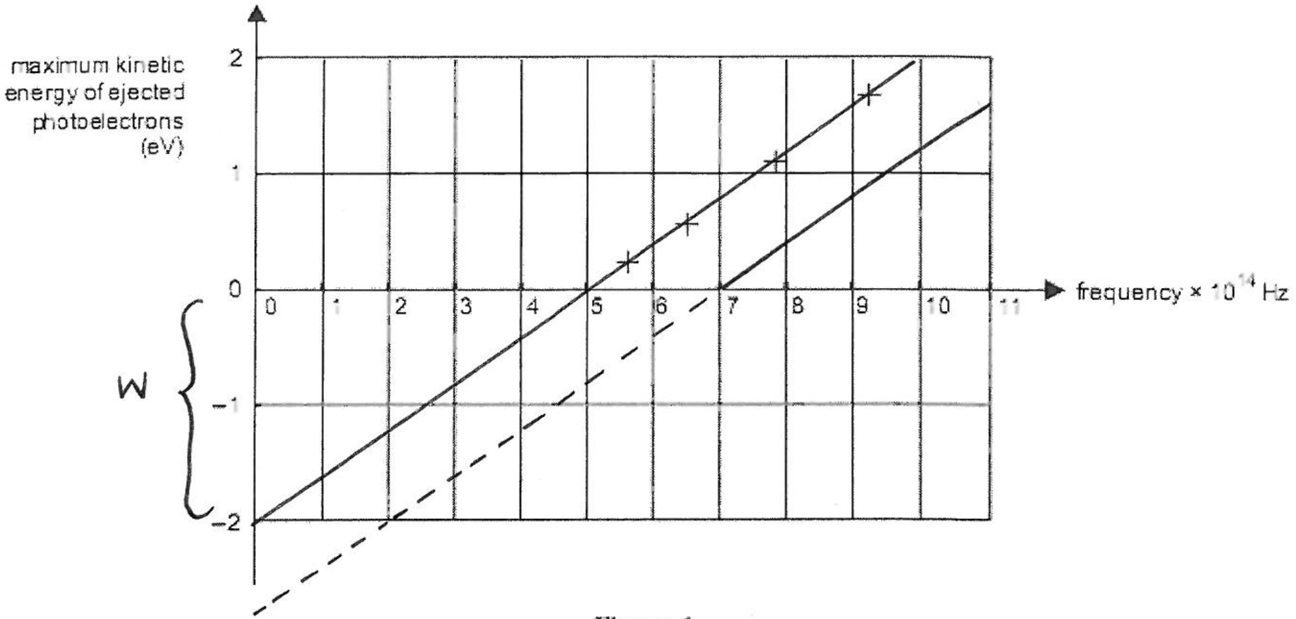


Figure 1

In answering the following questions, you must use the data from the graph

5a) What is the minimum energy, W (known as the work function), required to remove photoelectrons from the rubidium plate?

USING THE GRAPH : THIS CORRESPONDS WITH THE "Y" INTERCEPT (THE ENERGY AXIS) OF THE LINE OF BEST FIT.

THUS THE MINIMUM ENERGY IS 2 eV.

(2 marks)

5b) With what maximum kinetic energy would the photoelectrons be emitted when the students shine light of wavelength λ = 400 nm onto the rubidium plate?

$$E = h\,c/\lambda = \frac{6.62\times10^{-34}\times 3.00\times10^{8}}{400\times10^{-9}} = 4.965\times10^{-19}\ \text{J}$$

$$= 3.1\ \text{eV}$$

SINCE $E = W + E_K$

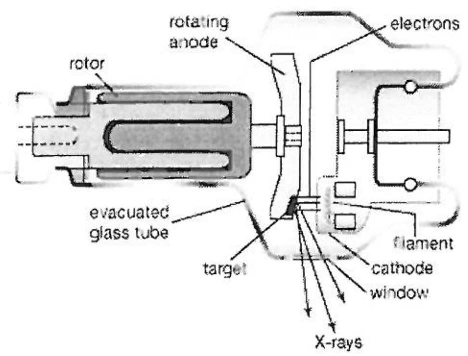
$$E_K = E - W = 3.1 - 2.0 = 1.1\ \text{eV}$$

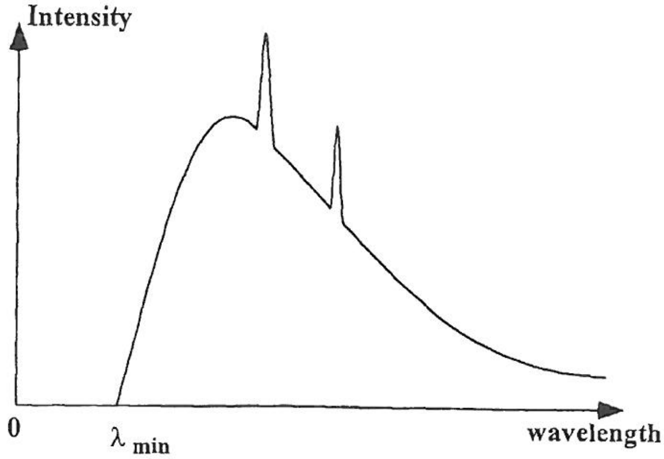
(2 marks)

5c) Sketch, on the axes above, the graph for a metal with a greater work function than that originally shown. GRADIENT IS PLANCK'S CONSTANT ! (MUST BE PARALLEL) (1 mark)

Q6 [5 marks]

The x-ray spectrum produced by a typical commercial tube exhibits features such as those shown in the diagram.





"BREMSSTRAHLUNG"

6a) Carefully explain how the broad band continuous component of the spectrum arises?

HIGH ENERGY/SPEED ELECTRONS UNDERGO A RAPID DECELERATION ON COLLISION/CLOSE INTERACTION WITH TARGET METAL ATOMS.

THE RAPID ΔE_K GIVES RISE TO A RANGE OF X-RAY PHOTONS OF VARYING WAVELENGTH/ENERGY (AND MUCH HEAT IS PRODUCED TOO)

(2 marks)

6b) Carefully explain why characteristic peaks form for a particular target metal?

ELECTRON COLLISION/INTERACTION MAY RESULT IN LOW ENERGY LEVELS (SHELLS) BEING EJECTED.

ELECTRONS FROM HIGHER ENERGY (OUTER SHELL) FALL BACK TO REPLACE THE VACATED ELECTRONS AND THE ATOM THEREBY RELEASES THE ENERGY ASSOCIATED WITH THIS TRANSITION AS AN X-RAY PHOTON OF SPECIFIC QUANTA.

THE "SPIKES" ARE CHARACTERISTIC/SPECIFIC TO THE TARGET METAL AND THEIR INTENSITY IS INCREASED/RE-INFORCED AS THESE SPECIFIC EMISSIONS SUPERPOSE WITH THE CONTINUOUS "BREMSSTRAHLUNG" SPECTRUM.

(3 marks)