ARANMORE CATHOLIC COLLEGE

YEAR 12 PHYSICS 3A3B – 2010

TOPIC TEST – ELECTROMAGNETIC RADIATION

NAME: SOLUTIONS.

MARK: /50

Instructions:

1. Answer all questions in the spaces provided.
2. Show full working out to get marks as shown in brackets after each question.
3. Answers should be in decimal form and show correct use of significant figures.
4. Calculators as per Curriculum Council guidelines are permitted.
5. Where practical answers must be in blue or black ink.

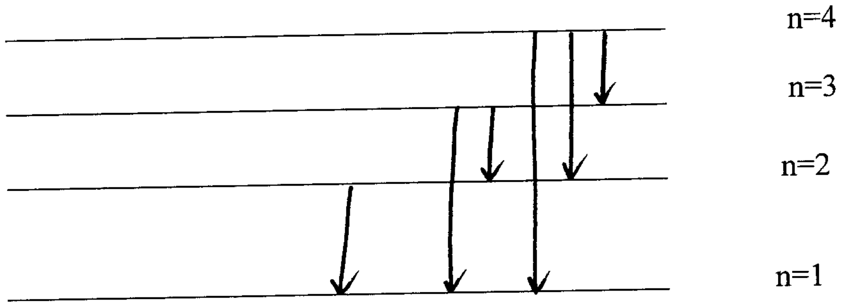
Note: Planck's Constant $h = 6.63 \times 10^{-34}$ J.s $1 \text{ eV} = 1.6 \times 10^{-19}$ J

Questions:

1. Describe Young's double-slit experiment and explain how it supports the theory that light travels as a wave. [4 marks]

- DIAGRAM AND/OR DESCRIPTION
- DIFFRACTION OF LIGHT THROUGH TWO NARROW SLITS
- INTERFERENCE PATTERN FORMS
- BRIGHT DUE TO CONSTRUCTIVE, DARK DUE TO DESTRUCTIVE INTERFERENCE OF WAVES.

2. Argon gas is excited with sufficient energy to reach the n=4 energy level as shown in the diagram below:



a) How many lines would there be in the emission spectrum? [2 marks]

6 LINES (1 MARK FOR 3 LINES)

b) On the diagram above, clearly label each of the transitions which would give rise to these lines. [3 marks]

(1 MARK EACH GROUP)

c) If ΔE (n=3 → n=1) is 6.7 eV, then what would be the frequency and wavelength of an emitted photon arising from this transition? [3 marks]

$\Delta E = 6.7 eV$

$= 6.7 \times 1.6 \times 10^{-19}$

(1) $= 1.072 \times 10^{-18}$ J.

(1) $E = hf$ so $f = \frac{1.072 \times 10^{-18}}{6.63 \times 10^{-34}} = 1.6 \times 10^{15}$ Hz.

(1) $c = f\lambda$ $\lambda = \frac{3 \times 10^{8}}{1.6 \times 10^{15}} = 1.9 \times 10^{-7}$ m (190 nm)

3. Classify the type of spectra produced by each of the following situations:

a) A sodium vapour street light LINE EMISSION

b) An incandescent light globe CONTINUOUS

c) A fluorescent tube BAND EMISSION

d) Sunlight LINE ABSORPTION

[4 marks]

4. Taylah and Steven repeated the photoelectric effect experiment by shining an ultraviolet light with a wavelength of 380 nm onto a clean metal surface. The stopping voltage was measured to be 1.5 V.

a) Calculate the energy of the incident photons. [2 marks]

$\lambda = 3.8 \times 10^{-7} m$; $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{3.8 \times 10^{-7}}$

$= 5.2 \times 10^{-19} J.$

[OR 3.27 eV.]

b) Calculate the maximum kinetic energy of the resulting photoelectrons? [2 marks]

$V_0 = 1.5 V$; $E_{K,MAX} = 1.5 eV$

$= 1.5 \times 1.6 \times 10^{-19}$

$= 2.4 \times 10^{-19} J.$

c) Explain why no photocurrent is produced when the stopping voltage is applied between the cathode and the anode. [2 marks]

- AT THIS VOLTAGE, EVEN THE MOST ENERGETIC ELECTRONS DO NOT HAVE SUFFICIENT KINETIC ENERGY TO OVERCOME THE (REVERSE) POTENTIAL DIFFERENCE BETWEEN THE ANODE AND CATHODE.

d) What is the work function of this metal? [2 marks]

$hf = 3.27 eV$; $hf = W + E_{K,MAX}$

$E_{K,MAX} = 1.5 eV$; $W = hf - E_{K,MAX} = 3.27 - 1.5 = 1.77 eV.$

[OR $W = 2.8 \times 10^{-19} J.$]

e) What is the threshold frequency of this metal? [2 marks]

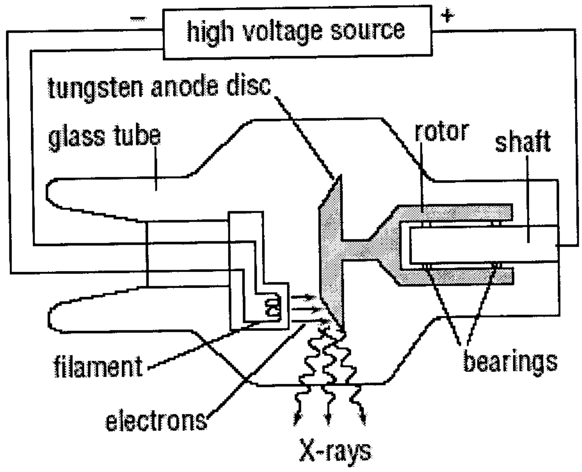
$W = h f_0$

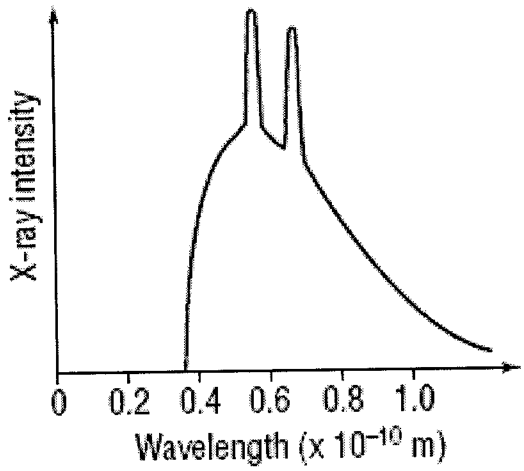
$f_0 = \frac{W}{h} = \frac{2.8 \times 10^{-19}}{6.63 \times 10^{-34}} = 4.2 \times 10^{14} Hz.$

f) Explain why no photocurrent is produced when light of frequencies below the threshold frequency in part (e) is used even at high intensities. [2 marks]

- INSUFFICIENT ENERGY OF INDIVIDUAL PHOTONS TO REMOVE AN ELECTRON BOUND TO THE METAL
- ELECTRONS CAN ONLY ABSORB ONE PHOTON AT A TIME, SO INTENSITY MAKES NO DIFFERENCE.

5. The diagrams below show a typical X-ray machine and the type of spectra it produces.





a) During operation the tungsten anode disc is rotated. Suggest reasons why they have to rotate the disk.

[2 marks]

- MOST OF THE ENERGY FROM ELECTRONS IS CONVERTED TO HEAT
- ROTATING DISPERSES HEAT OVER LARGER AREA, WHICH REDUCES TEMP RISE AND PREVENTS DAMAGE /MELTING.

b) What is the frequency of the shortest wavelength X-ray produced by this machine?

[2 marks]

FROM GRAPH: $\lambda_{MIN} \approx 3.5 \times 10^{-11} m.$

$c = f\lambda$

$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{3.5 \times 10^{-11}} = 8.6 \times 10^{18}\, Hz.$

c) What *high voltage*, in kV, is being used to produce this spectrum?

[4 marks]

$E = hf$

(1) $= 5.7 \times 10^{-15}\, J$

(1) OR $E = 35600\, eV.$

(1) SO $E_{k,MAX} = 35600\, eV.$

(1) $V = 35.6\, kV.$

d) Briefly explain the origin of the "spikes" in the intensity versus wavelength graph. [2 marks]

– LINE EMISSION SPECTRA OF THE PARTICULAR METAL ANODE

– INNER ELECTRONS HAVE BEEN 'KNOCKED OUT' AND THEN EMISSION OCCURS WHEN IT IS FILLED BY ELECTRONS FROM HIGHER ENERGY LEVELS.

e) How would the intensity versus wavelength graph change if

i) you used a different metal element for the anode [1 mark]

– POSITION OF SPIKES WOULD CHANGE (CHARACTERISTIC OF NEW METAL)

ii) you used a slightly higher voltage to accelerate the electrons [1 mark]

– λ_{MIN} WOULD DECREASE SLIGHTLY (INTENSITY WOULD ALSO INCREASE SLIGHTLY.)

COMPREHENSION QUESTION

Read the article below and answer the questions that follow.

Luminescence: emission of light by means other than combustion and therefore occurring at lower temperatures than are required for combustion. An example of luminescence is the light, or glow, emitted by a luminous watch dial. Luminescence contrasts with incandescence, which is the production of light by heated materials.

When certain materials absorb various kinds of energy, some of the energy may be emitted as light. This process involves two steps:
(1) The incidental energy causes the electrons of the atoms of the absorbing material to become excited and jump from the inner orbits of the atoms to the outer orbits
(2) When the electrons fall back to their original state, a photon of light is emitted. The interval between the two steps may be short (less than 1/100,000 of a sec) or long (many hours). If the interval is short, the process is called fluorescence; if the interval is long, the process is called phosphorescence. In either case the light produced is almost always of lesser energy, that is, of longer wavelength, than the exciting light. Fluorescence and phosphorescence have a number of practical applications. The picture screens in television receivers are coated with fluorescent materials known as phosphors that glow when excited by a cathode ray (see Cathode-Ray Tube). The interiors of fluorescent lamps have similar coatings, which absorb the invisible but intense ultraviolet components of the primary light source and emit visible light. A special type of fluorescence called stimulated emission occurs in the operation of a laser.

Chemiluminescence is caused by chemical reaction, as when yellow phosphorus oxidizes in air, emitting green luminescence. If the chemical reaction takes place in a living organism, such as the firefly, the process is called bioluminescence.
Triboluminescence is luminescence that results from the breaking, scratching, or pulling apart of certain materials.
Electroluminescence is luminescence created by a gas in the path of an electrical discharge; examples are lightning and the light of a fluorescent lamp.
Photoluminescence is luminescence created when certain materials are irradiated by visible light or ultraviolet light; an example is the phosphorescence of paints. Roentgenoluminescence is luminescence produced by X-rays bombarding certain materials; an example is X-rays on a fluoroscope screen.
Sonoluminescence, observed in some organic liquids, is luminescence produced by ultrahigh-frequency sound waves, or ultrasound.

6. a) What is the difference between fluorescence and phosphorescence? [2 marks]

- FLUORESCENCE, EXCITED ELECTRONS RETURN TO GROUND START ALMOST IMMEDIATELY.
- PHOSPHORESCENCE, EXCITED ELECTRONS DECAY MORE SLOWLY.

b) An aged physics professor was heard talking to one of his students: *"I was standing in this pitch black darkroom with my eyes closed when I heard the X-ray machine turn on....it's on a timer. I could swear that I could see a pale yellow glow! Do you think I am having illusions?"* Explain why the professor may not have been having illusions.

[3 marks]

- ROENTGENOLUMINESCENCE
- X-RAYS PENETRATE EYELIDS
- X-RAYS EXCITE SUBSTANCE IN EYE WHICH FLUORESCES WITH YELLOW LIGHT.

(c) A high intensity ultrasonic sound source is directed at a rectangular plate of material. The plate starts to glow and emits visible light.

i. What is the name given to this effect?

[2 marks]

- SONOLUMINESCENCE

ii. If the power of the ultrasonic sound incident on the plate is 45 W, estimate the maximum number of photons that the plate can emit each second.

[3 marks]

(1) $f = 1 \times 10^{15}\ Hz$

(1) $E = hf = 6.63 \times 10^{-19}\ J$

(1) $N = \frac{45\ Js^{-1}}{6.63 \times 10^{-19} J} = 7 \times 10^{19}$ PHOTONS s^{-1}.

- ASSUMING 100% EFFICIENCY.

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END OF TEST