

### Exam 2 (April 11, 2007)

*Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where requested in order to be considered for partial credit. In problems where you are requested to show your work, no credit will be given unless your work is shown.*

#### **Problem 1 (12 pts, no need to show work):**

Quotes that might have been ... next to each of the fictitious quotes, put the letter of the person we have studied who would most likely have said it based on your knowledge of what that person is known to have done.

*Example*

A "If the Iranians were to have a nuclear weapon, they could proliferate." (Not fictitious. Yikes!)

J "With my new wave equation for matter, you can solve for the allowed states of the electron in the hydrogen atom."

G "Officer, if I knew exactly how fast I was going, I would have no idea where I was."

N "The atom, it appears, is mostly empty space with most of the mass and positive charge concentrated in a very small region."

O "Photons with discrete and specific energies are emitted as the electron moves from one circular orbit to one of lower energy."

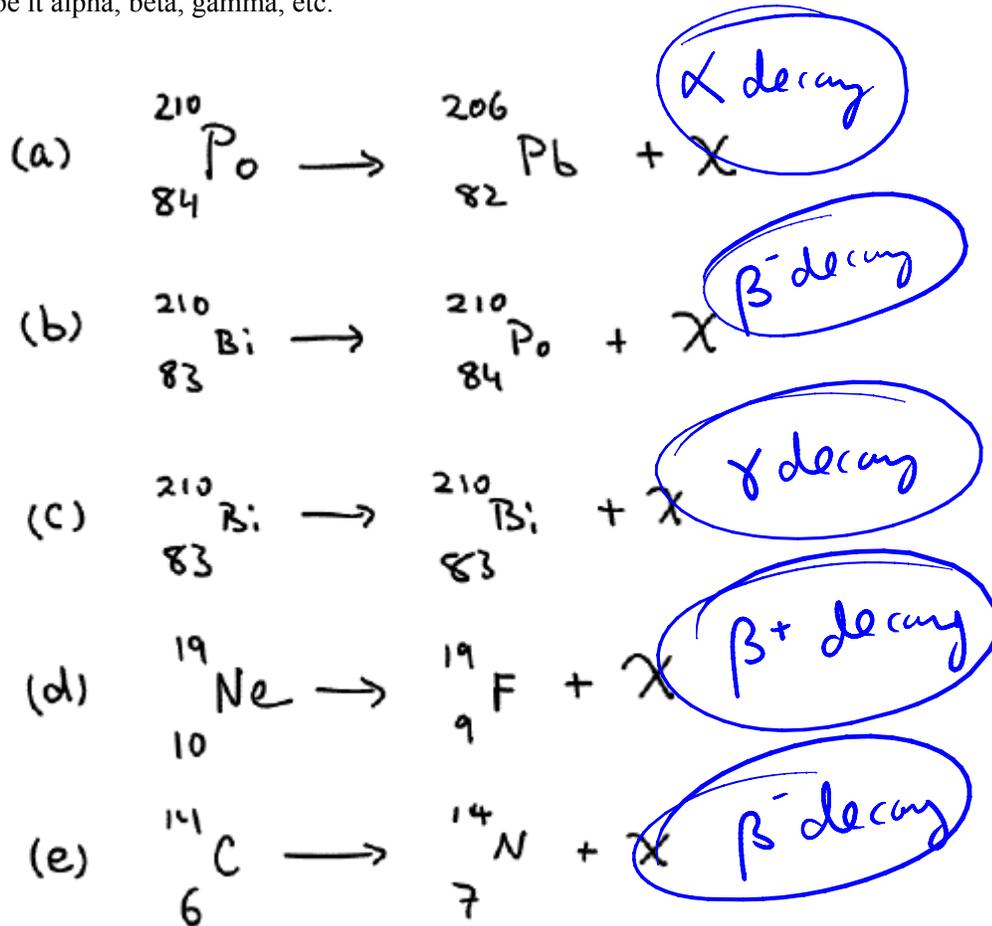
E "Photons are absorbed when light is shown on the metal plate causing electrons to be ejected."

B "The electron in an atom exists as a sum of possibilities until it is observed. All we can determine is the probability that it will be seen in this state or that state."

- A. George W. Bush
- B. Max Born
- C. Otto Stern
- D. Louis de Broglie
- E. Albert Einstein
- F. Isaac Newton
- G. Werner Heisenberg
- H. Alan Guth
- I. Edwin Hubble
- J. Erwin Schroedinger
- K. Joel Seligman
- L. Roentgen
- M. Max Planck
- N. Rutherford
- O. Niels Bohr
- P. P.A.M Dirac

**Problem 2 (10 pts, no need to show work):**

Below are shown five radioactive decays. Label each as to whether it is an example of alpha decay, beta decay or gamma decay. "X" represents whatever other stuff comes out in the reaction, be it alpha, beta, gamma, etc.



Scores	
1.	___/12
2.	___/10
3.	___/5
4.	___/10
5.	___/7
6.	___/8
7.	___/10
8.	___/6
9.	___/6
10.	___/6
11.	___/5
12.	___/8
13.	___/7
Total ___/100	

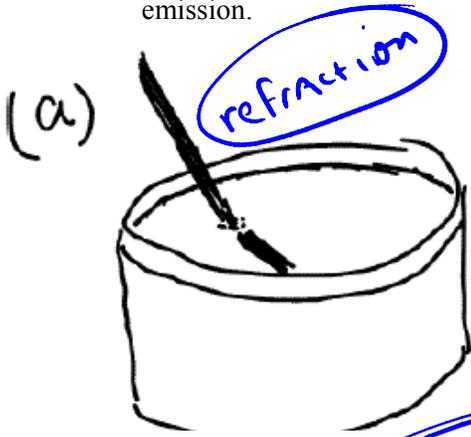
**Problem 3 (5 pts, no need to show work – multiple choice – circle correct answer):**

Hydrogen must be raised to a high temperature before it will fuse. This is because

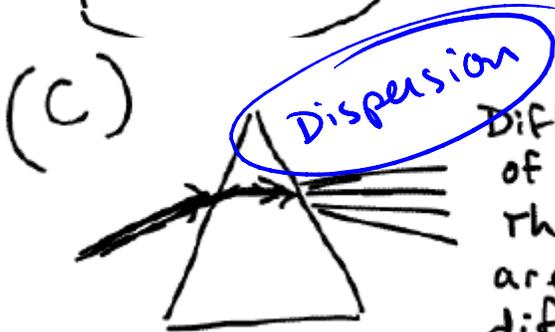
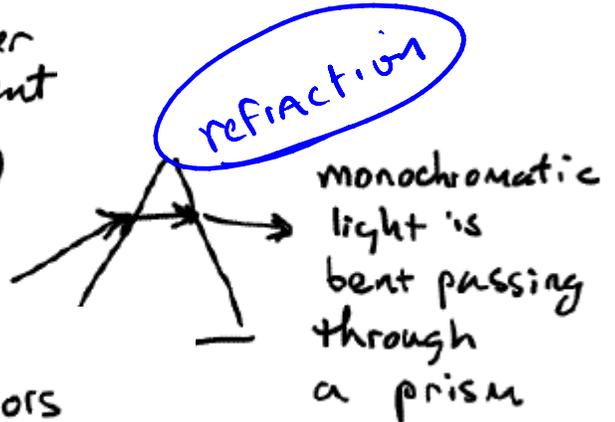
- a) this reaction consumes more thermal energy than it produces.
- b) high temperatures are needed to overcome the electric repulsion between hydrogen nuclei.
- c) fusion and all other chemical reactions must be initiated by high temperatures. ← 2PTS
- d) high temperatures are needed to overcome the strong force between the hydrogen nuclei.
- e) this reaction consumes a large amount of thermal energy by virtue of where the reactants sit on the binding energy per nucleon versus A curve.

**Problem 4 (10 pts, no need to show work):**

State which physical process is responsible for the wave phenomenon described/shown. Physical process choices are reflection, refraction, diffraction, interference, dispersion, absorption, emission.



STRAIGHT STRAW  
immersed in water  
appears to be bent

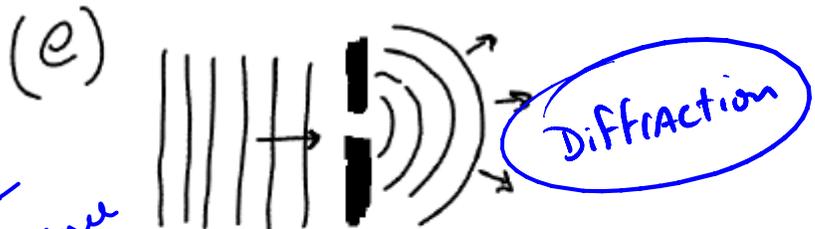


Different colors  
of light passing  
thru a prism  
are bent  
differing amounts  
 $\frac{1}{2}$  credit  $\rightarrow$  refraction



A concert takes place on the  
quad. Two speakers are  
set up, separated by  
10 meters. You find as you  
walk around the quad a certain

distance from the stage, there are places where  
the music is quite loud and other places where  
the music is significantly quieter.

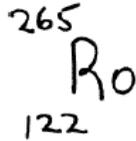


$\frac{1}{2}$  credit -  
interference

STRAIGHT water waves incident  
on a hole in a reef spread  
out in a semicircular pattern as  
they move away from the hole  
into the lagoon beyond.

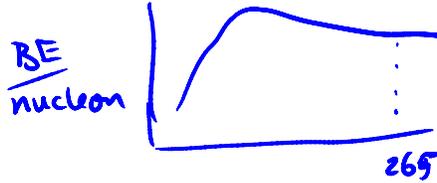
**Problem 5 (7 pts, no need to show work):**

As part of a Physics 100 project a group of students discovered a new element which they call Rochesteronium. The atomic symbol for Rochesteronium is Ro. The most prevalent isotope the students found is



- a) How many protons are in a nucleus of Rochesteronium? **122 protons**
- b) How many neutrons are in the isotope of Rochesteronium?  **$265 - 122 = 143$  neutrons**
- c) If a nucleus of helium ( $z=2$  and  $A=4$ ) fused with a nucleus of Rochesteronium, would you expect energy to be absorbed or released? Why?

Energy would be absorbed -  
at large  $A$ , increasing  $A$  leads  
to lower binding energy/nucleon



**Problem 6 (8 pts):**

→ TAKES energy rather than releasing energy.

You go for a walk with one of your friends late a night. There's a power outage in Rochester and the sky is clear and beautiful. Your friend knows you are a closet science geek. So, they ask you, "How does the sun work?" Briefly write below what you would tell your friend.

The sun is a large ball of (mostly) hydrogen gas which is compressed and heated under the influence of gravitation. The inward force of gravity is balanced by an outward force of heat (radiation pressure). The source of heat comes from nuclear fusion reactions in the core of the sun where energy is released when hydrogen nuclei are fused into helium nuclei.

**Problem 7 (10 pts, show work):**

Radium-226 is a common radioactive element on Earth. It has a half-life of 1600 years.

a) If you enclosed a sample of 2 grams of Radium-226 in a box and buried it, how much Radium-226 would you expect to be present in the box after 4800 years?

4800 yrs ~ 3 half lives - so, expect fraction left to be  $(\frac{1}{2})(\frac{1}{2})(\frac{1}{2}) = \frac{1}{8}$   
or  $2/8 = \frac{1}{4}$  gram

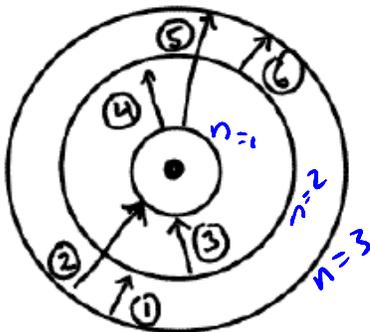
b) The Earth is almost 5 billion years old and the half-life of Radium-226 is 1600 years. How is it that Radium-226 is commonly found on Earth?

Other radioactive isotopes must decay into Radium-226

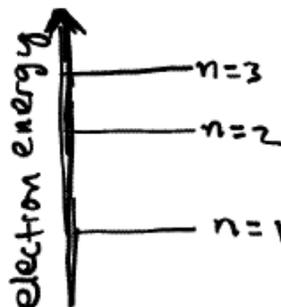
**Problem 8 (6 pts, no need to show work):**

Below is the sketch of the orbits in the Bohr model of the hydrogen atom. Shown are six possible transitions for the electron in this atom along with a corresponding energy level diagram. Also shown is a schematic spectrum of light emitted by the atom. Which of the six transitions corresponds to the process giving rise to the light contributing to each of the three spectral lines? (Label each of the three spectral lines with the number of the transition shown.)

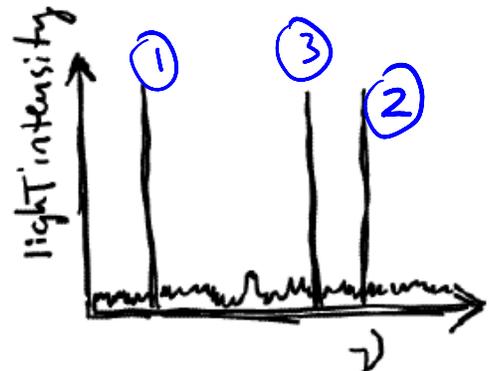
Hydrogen Atom with six possible transitions



energy levels (schematic)



spectrum of bright light emitted by atom



light emitted → electron must be moving down in n or from outer shells to inner shells. Most energetic from  $n=3 \rightarrow n=1$ , least energetic from  $n=3 \rightarrow n=2$ .

Energy proportional to  $\nu$

**Problem 9 (5 pts, no need to show work):**

Arrange in the order of increasing photon energy (smallest energy on the left and highest energy on the right):

X-ray, red light, radio wave, blue light, infrared light, microwave

radio < microwave < infrared < red < blue < X-ray

**Problem 10 (6 pts, show work):**

A typical wavelength of infrared radiation emitted by your body is  $25 \mu\text{m}$  ( $2.5 \times 10^{-5} \text{ m}$ ).

a) What is the approximate speed of the photons in this light?

$$c = 3 \times 10^8 \text{ m/s}$$

b) What is the frequency of this light?

$$c = \lambda \nu \quad 3 \times 10^8 = 2.5 \times 10^{-5} \nu$$

$$\nu = \frac{3 \times 10^8}{2.5 \times 10^{-5}} = 1.2 \times 10^{13} \text{ Hz}$$

c) What is the energy of the photons in this light?

$$E = h \nu$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$E = (6.63 \times 10^{-34})(1.2 \times 10^{13}) = 8 \times 10^{-21} \text{ Joules}$$

$$= 8 \times 10^{-21} \text{ J} \times \frac{1 \text{ eV}}{1.6 \times 10^{-19} \text{ J}} = 0.05 \text{ eV}$$

**Problem 11 (5 pts, show work):**

What is the de Broglie wavelength of electrons striking the back of the face of a television screen? (Assume these electrons are moving at approximately 1/10 the speed of light at the time they strike the screen.)

$$\lambda = \frac{h}{mv}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$\lambda = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.11 \times 10^{-31} \text{ kg})(3 \times 10^8 \text{ m/s}) \frac{1}{10}} = 2.4 \times 10^{-11} \text{ m}$$

$$\lambda = .02 \text{ nm}$$

**Problem 12 (8 pts):**

Sunburn produces cell damage in the skin. Why is ultraviolet radiation capable of producing this skin damage while visible radiation, even if more intense, does not cause this damage?

The photons in UV light have more energy than the photons in visible light. The UV photons have enough energy to cause cell damage whereas the visible photons do not.

This is rather similar to the photoelectric effect where the photons must be energetic enough to eject the electrons... which means the electrons are only ejected if the light has a high enough frequency.

**Problem 13 (7 pts):**

How does laser light differ from a narrow, intense beam of light from a flashlight?

Laser light is coherent and monochromatic.

single frequency

Each photon added to the light wave come in with constructive interference and in the same direction.

This yields a very intense, monochromatic beam.

Light from a flashlight comes from many atomic transitions (not monochromatic) and the sources do not add coherently

(meaning sometimes the light adds constructively and sometimes destructively)   
 or interferes