

Exam 2 (October 14, 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 (6 pts, no need to show work):

Ernest Rutherford's experiments in which he (or his students) observed the scattering of alpha particles as they passed through a thin metal foil demonstrated that

- a) light is a wave.
- b) Light is made of particles
- c) The atom has a tiny positive nucleus containing most of the atom's mass.
- d) Electrons exist.
- e) Neutrons exist.

Problem 2 (6 pts, no need to show work):

A neutral atom's "atomic number" represents the

- 4 PTS → a) number of protons in the nucleus.
- 4 PTS → c) the number of electrons orbiting the nucleus of the atom.
- 6 PTS → f) both (a) and (c).
- b) the number of neutrons in the nucleus.
- d) the number of quantum mechanical energy levels in the atom.
- e) the number of protons and neutrons in the nucleus.

Problem 3 (6 pts, no need to show work):

The sun's energy comes from

- 2 PTS → a) nuclear decay.
- 6 PTS → b) nuclear fusion.
- c) excessive amounts of jolt cola.
- d) nuclear fission.
- e) chemical reactions.

Problem 4 (6 pts, no need to show work):

If two atoms are the same and are bound together in a molecule (such as H₂ or O₂) the chemical bond between them is

- 6 PTS → b) a covalent bond.
- 2 PTS → d) an ionic bond.
- a) a quantum entanglement.
- c) an example of the photoelectric effect.
- e) all of the above

Problem 5 (6 pts, no need to show work):

The alpha decay of an atom of $^{238}_{92}\text{U}$ yields the atom

- 3 pts → a) $^{234}_{90}\text{U}$
- b) $^{238}_{90}\text{Th}$
- c) $^{238}_{93}\text{Np}$
- d) $^{238}_{91}\text{Pa}$
- 6 pts → e) $^{234}_{90}\text{Th}$

↳ $^{234}_{90}\text{X}$ but not U since Z has changed

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

According to our scientific understanding of stars, most of the atoms of heavy elements (heavier than iron) that are spread throughout the dust in the universe were created

- 2 pts → a) as dust clouds collapsed to form young stars
- 6 pts → b) during the fusion process that powers the stars, and then released by a supernova explosion.
- 6 pts → c) during a supernova explosion.
- d) in the middle of hot white dwarf stars.
- e) in Danforth and launched in to space by bottle rockets.

Problem 7 (6 pts, no need to show work):

In quantum mechanics, if two photons are “entangled” it means

- 6 pts → a) they always move in the same direction.
- 6 pts → b) the two photons share the same quantum wavefunction and observations of one are reflected in the state of the other.
- c) they are moving directly away from one another.
- 2 pts → d) the two photons share the same quantum wavefunction and, consequently, observations of one have no bearing on the other.
- e) they had a bit much to drink the night before.

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

One difference between electrons and photons is

- 3 pts → a) electrons are particles while photons are waves.
- 3 pts → b) electrons are a particle of matter and photons are a particle of light.
- 6 pts → c) both of the above.
- d) photons obey quantum theory while electrons obey Newtonian physics.
- e) all of the above.

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

Wow! 😊

Problem 9 (10 pts):

A neutron makes a much more effective "nuclear bullet" for fissioning a nucleus, e.g., in a chain reaction, than does a proton. Why?

The proton has positive electric charge, as does a nucleus. Consequently a proton is repelled by a nucleus as it approaches. This is NOT true for a neutron.

Problem 10 (10 pts):

Why is it that the spectrum of light emitted by an atom is often said to be a "fingerprint" for that atom?

The discrete frequencies of light emitted by an atom come from the electron making transitions between the particular discrete energy levels available in that atom. This is a "fingerprint" since the allowed quantum energy levels for the electron depend on the # of "+" charges in the nucleus (Z) and this is unique for each type of atom (or element).

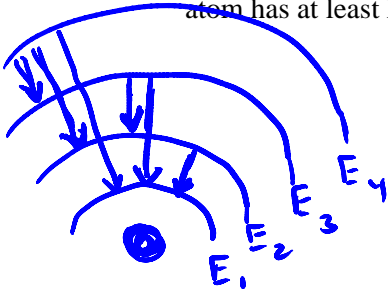
Problem 11 (10 pts):

If there are only approximately 100 different atomic elements (types of atoms) in our world, how is it that you can identify many, many more than 100 different types of substances in the world around you?

Atoms can combine ^{together} into chemical compounds creating substances with new and different properties.

Problem 12 (10 pts, show work):

You pass white light through an atomic gas and then a prism. When you look at the pattern of light coming out of the prism, you notice that six specific colors (or frequencies) of light have been absorbed by the gas. According to the Bohr model, this data tells you that the electron in the atom has at least how many energy levels?



e^- in this atom has 4 different energy levels it can occupy.

Arrows represent possible transition emitting photons.

Problem 13 (12 pts, show work):

Suppose we find a rock and geologists tell us that when that rock was formed in a volcano it would have contained an equal amount of Iridium-192 ($Z=77$, symbol = Ir) and Bismuth-209 ($Z=83$, symbol = Bi). Suppose that Iridium-192 and Bismuth-209 are both naturally radioactive. Also, suppose that Iridium-192 decays with a half-life of 500,000 years and Bismuth-209 decays with a half-life of 1 million years. If the rock is two million years old and you measure the amount of Iridium-192 and Bismuth-209 in the rock, what ratio for the amount of Iridium-192 to Bismuth-209 would you expect to measure?

2 million years represents 2 half-lives for Bi-209
and 4 half-lives of Ir-192

START w/ x grams of Bi-209 $\xrightarrow{\text{AFTER 2 MYRS}}$ $(\frac{1}{2})(\frac{1}{2})x = \frac{1}{4}x$

" " " " " Ir-192 $\rightarrow (\frac{1}{2})(\frac{1}{2})(\frac{1}{2})(\frac{1}{2}) = \frac{1}{16}x$

at end of 2m yrs

$$\frac{\text{Ir-192}}{\text{Bi-209}} = \frac{\frac{1}{16}x}{\frac{1}{4}x} = \frac{4}{16} = \frac{1}{4}$$

Some potentially useful formulas

$$F = \frac{G m_1 m_2}{r^2}$$

$$F = \frac{k q_1 q_2}{r^2}$$

$$F = ma$$

$$(\text{distance}) = (\text{Speed})(\text{time})$$

$$V = \frac{\Delta x}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$

$$\text{Work} = \text{force} \times \text{distance}$$

$$\text{Momentum} = p = mv$$

$$\Delta x' = \gamma \Delta x, \Delta x \text{ longest in proper frame}$$

$$\Delta t' = \gamma \Delta t, \Delta t \text{ shortest in proper frame}$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

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

$$h = 6.6 \times 10^{-34} \text{ J}\cdot\text{s}$$

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

$$v = \lambda \nu$$

$$\nu = \frac{1}{T} \quad (T = \text{period})$$

$$\Delta x \Delta p > h \quad \Delta E \Delta t > h$$

$$E = h\nu$$

$$\frac{\Delta N}{\Delta t} = \lambda N$$

$$t_{1/2} = \frac{0.693}{\lambda}$$