P102 University of Rochester NAME Soln key - SLM
S. Manly Spring 2011

Exam 2 (April 20, 2011)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary.

Problem 1 (6 pts, no need to show work, circle best answer):

The fundamental force responsible for the chemical properies of atoms is

- a) gravity
- 6 - [✓ b)] electromagnetism
- c) weak nuclear force
- 2 - d) strong nuclear force
- e) dark matter attraction

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

The formation of light nuclei such as lithium (the process of big bang nucleosynthesis), is thought to have happened approximately how long after the beginning of the big bang according the the standard hot, big bang model of cosmology?

- a) 10^{-35} seconds
- b) 10^{-6} seconds
- c) 1 second
- [✓ d)] 100 seconds
- e) 400,000 years

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

In the inflationary hot big bang model, cosmological inflation is thought to have happened when?

- a) 1985
- b) 13.2 million years ago
- c) 13.7 million years ago
- [✓ d)] 13.7 billion years ago
- e) 13.7 trillion years ago

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

____

Total ___/100

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

In quantum field theory, the force that binds quarks into protons arises from the exchange of

6 – [✓ a)] gluons
b) pions
c) W bosons
2 – d) photons
e) higgs bosons

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

Forms of radioactivity emitted by unstable/quasi-stable nuclei found in nature include:

2 – a) gamma photons, beta particles, UV photons
2 – b) UV rays, alpha particles, x-rays
c) W particles, gluons, pions
6 – [✓ d)] Alpha particles, beta particles, gamma rays
e) Pions, gamma rays, alpha particles

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

Protons are an example of a

a) Meson made of a quark and an antiquark
6 – [✓ b)] Baryon made of three quarks
2 – c) Baryon made of three leptons
d) Gauge boson made of a pion and an antipion
e) Gauge boson made of three gluons

Problem 7 (8 pts, show work):

It takes 6400 years for one gram of radium to decay away to only 1/16 or a gram. Determine the half-life of radium.

$1\,t_{1/2} \rightarrow 1/8$ g

$2\,t_{1/2} \rightarrow 1/4$ g

$3\,t_{1/2} \rightarrow 1/2$ g

$4\,t_{1/2} \rightarrow 1$ g

radium goes from 1g → 1/16 g in 4 half-lives

$$\frac{6400}{4} = \boxed{1600 \text{ years} = 1 \text{ half-life}}$$

1600 1 → 1/2
3200 1/2 → 1/4 ✓
4800 1/4 → 1/8
6400 1/8 → 1/16

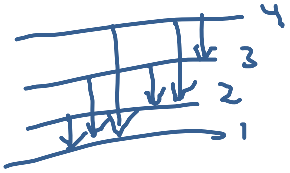
Problem 8 (8 pts):

Briefly explain how it is that two different isotopes of an atom can have similar chemical properties but very different nuclear stabilities.

Different isotopes have different numbers of neutrons but the same number of protons. The number of protons determines the electric charge of the nucleus, and thus the electronic orbital structure and chemistry (since chemistry involves changes in electron arrangements). Since the number of neutrons plus protons differs, it is natural that the nuclear structure will differ between isotopes.

Problem 9 (8 pts, show work):

According to the Bohr model of the atom, if a certain type of atom emits six discrete frequencies of light, how many potential electron orbits (energy levels) exist in that type of atom?



4 levels

Problem 10 (8 pts):

If you encountered a little pile of uranium would you be more concerned about radioactivity arising from the process of nuclear fusion or the process of nuclear fission? Why? Fission.

uranium is a large nucleus (larger than iron). It will naturally undergo fission, but not fusion (because there would be a net loss of energy for a nucleus of this size to undergo fusion.

So, the natural radioactivity emitted by the sample will come from fission.

Problem 11 (8 pts):

What fundamental force of nature is responsible for the nuclear fusion that powers stars? Briefly defend your answer (why do you say what you do?).

The strong nuclear force. This is the force that binds small nuclei together, which is what we mean by "fusion"

I will accept an answer of "gravity" since gravity is the force that creates the energetic and dense conditions that make fusion possible in the stellar interior

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Problem 12 (8 pts):

The energy of motion of a particle is defined as (1/2)MV^2, where M is the mass of the particle and V is its velocity. Is it possible to know precisely the energy of a proton that is confined to a nucleus in carbon atom? Briefly explain why or why not?

No. One form of Heisenberg's uncertainty principle is $\Delta x \Delta V = h/m$
if the proton is confined to a nucleus, Δx is about 10^{-15} m.
ΔV will be finite. If there is uncertainty in V, there will be uncertainty (a spread) in $\frac{1}{2}MV^2$
||
Energy.

Problem 13 (8 pts):

2 of

Briefly describe two scientific observations that support the idea of the big bang.

- Expanding universe - galaxies are receding from each other
- cosmic Microwave Background - see light from an early stage of the Big Bang
- abundance of light (small) nuclei in intergalactic space consistent with formation at early stage of the Big Bang (so-called Big Bang nucleosynthesis)

Problem 14 (8 pts):

One of

If inflation actually happened (or is happening), the fact that we live in at least one multiverse is inevitable according to physicists. Briefly describe one type of mulitiverse that is thought to be present if inflation happened.

- as inflation continues, quantum fluctuations in the space-time (inflaton field) can cause inflation to slow/stop in scattered regions. Each of these regions could be thought of as a universe that is causally disconnected from other such regions (or bubbles). This is the bubble multiverse (or "level 2" according to Tegmark)
- The reality in which our universe resides is vastly larger than our observable (or potentially observable) universe. We can think of this reality as being made up of a Huge Number - infinite - of causally disconnected regions constituting a multiverse (my beyond-the-horizon multiverse, "level 1" for Tegmark)

Some potentially useful formulas

$$F = \frac{G m_1 m_2}{r^2} \left(\begin{array}{c} m_1 \text{ and } m_2 \text{ in kg} \\ r \text{ in meters} \end{array} \right) \rightarrow G = 6.7\times10^{-11}$$

$$F = \frac{k q_1 q_2}{r^2} \left(\begin{array}{c} q_1, q_2 \text{ in Coulombs} \\ r \text{ in meters} \end{array} \right) \rightarrow k = 9\times10^{9}$$

Force in Newtons

$F = ma$

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

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

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

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

$\text{Momentum} = p = mv$

$\Delta x' = \gamma \Delta x$, length longest in proper frame

$\Delta t' = \gamma \Delta t$, time shortest in proper frame

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

$1 \text{ Joule} = 1.6\times10^{-19} \text{ eV}$

$\text{speed of sound} = 330 \text{ m/s}$

$c = 3\times10^{8} \text{ m/s}$

$v = \lambda \nu$

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

gravitational force at earth's surface

$F = mg$ where

$$g = \frac{G M_E}{R_E^2} = 9.8 \text{ m/s}^2$$

$\Delta x \Delta p \gtrsim h$

or

$\Delta x \Delta v \gtrsim h/m$

$\Delta E \Delta t \gtrsim h$

$h = 6.63\times10^{-34} \text{ J s}$