Practice Test Questions 2
Atoms, Isotopes and Nuclear Chemistry

1. Fill in the blanks in the short paragraph below.

   Fluorine has only one stable isotope. Its mass number is _____. A neutral atom of fluorine has _____ protons, _____ neutrons and _____ electrons. Fluorine can only form one kind of ion. The charge of this ion is -1, and it is formed when fluorine__________________________ electron(s).

   The last blank should be filled in by indicating the number of electron(s) gained or lost and whether the electron(s) are gained or lost.

2. For most elements, none of the atoms has the exact mass listed on the periodic table. Briefly explain why this is the case.

3. Naturally occurring uranium contains the following isotopes:

Isotope	**Mass of Isotope**	**Percent Abundance**
^{234}U	234.040946 u	0.0055%
^{235}U	235.043923 u	0.7200%
^{238}U	238.050783 u	99.2745%

The only isotope of uranium that is useful in nuclear reactors is ^{235}U. Some reactors are able to use naturally occurring uranium; however, many kinds of reactors require something called "enriched uranium". In enriched uranium, some of the ^{238}U is removed. This increases the percent abundance of ^{235}U in the remaining uranium.

(a) The uranium used in the first uranium-based nuclear bomb contained about 80% ^{235}U. Calculate the average atomic mass for weapons grade uranium containing 80.00% ^{235}U. Assume that the percent abundance of ^{234}U is still negligible.

(b) If the quality of the uranium is increased by further increasing the percent abundance of ^{235}U, how will the average atomic mass of the uranium change?

4. There are two naturally occurring isotopes of copper (Cu). ^{63}Cu has an isotopic mass of 62.9296 u. ^{65}Cu has an isotopic mass of 64.9278 u. Calculate the percent abundance of each isotope of copper.

5. Write a balanced equation for each of the following nuclear reactions.

(a) ^{100}Zr decays to ^{100}Nb

(b) ^{212}Pb decays to ^{212}Bi

(c) ^{181}Pb decays to ^{177}Hg

(d) ^{11}N is transformed to ^{10}C

(e) ^{24}Na is transformed to ^{23}Na

6. Write a balanced equation for each of the following nuclear reactions.

(a) electron capture by ^{26}Al

(b) β-emission by ^{208}Au

(c) β^+-emission by ^{82}Zr

(d) a nuclear bombardment reaction in which ^{253}Es reacts with ^{4}He to produce a large nucleus and one neutron

(e) fission of ^{236}U to give ^{138}Xe and ^{95}Sr

7. While many different fusion reactions occur in stars such as our sun, the main one is the proton-proton chain reaction. In this reaction, four ^{1}H combine (in multiple steps) to give ^{4}He, two positrons, two neutrinos and gamma radiation.

(a) In the first step, two ^{1}H react to give ^{2}H and a neutrino ($^0_0\nu$). Write a balanced equation for this step.

(b) In the second step, one ^{2}H reacts with another ^{1}H to give ^{3}He and gamma radiation ($^0_0\gamma$). Write a balanced equation for this step.

(c) In the third step, two ^{3}He react to give ^{4}He. Write a balanced equation for this step.

(d) Demonstrate that these three steps combine to give the overall reaction described in the main part of the question.

8. Copernicium-277 (^{277}Cn) has been made by bombarding ^{208}Pb with ^{70}Zn.
The reaction produces ^{277}Cn and another product.

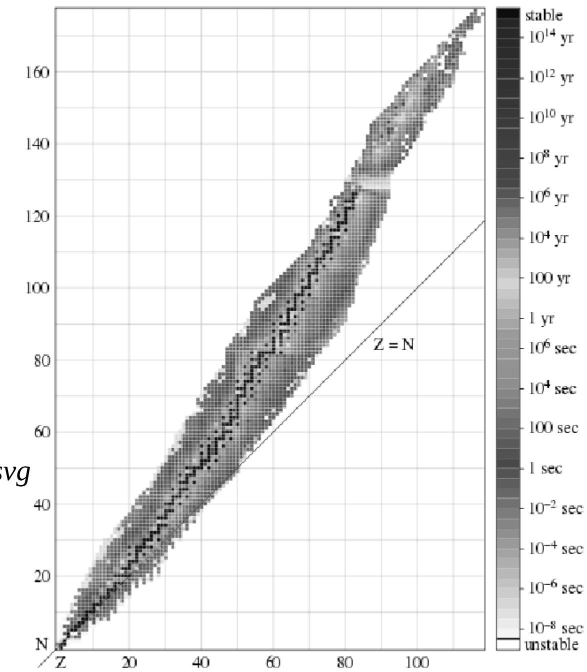
(a) Write a balanced equation for this reaction.

(b) How much energy does this reaction absorb or release per mole?
For clarity, state (in words) whether energy is absorbed or released.

$$M_{^{277}_{112}Cn} = 277.163\ 64\ \text{u}$$
$$M_{^{208}_{82}Pb} = 207.976\ 652\ 5\ \text{u}$$
$$M_{^{70}_{30}Zn} = 69.925\ 319\ 2\ \text{u}$$

Band of Stability Graph (on data sheets of all CHEM 1000 tests)

The graph at the right shows the band of stability.
Stable isotopes are in black. Isotopes that exist but are not stable are shown in varying shades of gray with the shades of gray corresponding to different half-lives.
The original version of the graph used a rainbow colour scale (see next page).
http://commons.wikimedia.org/wiki/File:Isotopes_and_half-life_eo.svg



9. For each of the isotopes listed below, use the band of stability graph to determine whether or not it is expected to be stable. For each of the unstable isotopes, predict which mode(s) of decay are most likely.

(a) ^{95}Mo (b) ^{7}Be (c) ^{47}K

(d) ^{35}K (e) ^{240}Es

10.

(a) Of the different types of ionizing radiation produced by nuclear reactions, alpha radiation has the lowest penetrating power. Why?

(b) Which type(s) of ionizing radiation would you expect to have the highest penetrating power? Why?

(c) How does penetrating power of different types of radiation affect safety considerations when working with radioactive isotopes?

11.

(a) What property is reported using the unit gray (Gy)? What is 1 Gy?

(b) What property is reported using the unit sievert (Sv)? What is 1 Sv?

12. A 25.0 g wooden artifact has a ^{14}C activity of 4.65 Bq. The ^{14}C activity in living material is 0.255 Bq/g, and the half-life of ^{14}C is 5730 years. Estimate the age of the wooden artifact and the earliest year in which the artifact could have been made. *(It is, of course, possible, that the artifact was made long after the tree was chopped down. You are estimating the year in which the tree was chopped down and the wood ceased to be living.)*

13. Jerri prepared a sample of ^{93}Tc and measured its activity to be 46.1 Bq. After 35 minutes, she measures the activity of the sample again, and it has decreased to 39.8 Bq. Assuming that the amount radiation produced by ^{93}Mo (the product of this decay) is negligible, calculate the half-life of ^{93}Tc.

14. In the 20th century, uranium was often used to produce brilliantly colored (often red-orange) ceramic glazes. Some colors of the Fiesta line of dinnerware in particular were produced using natural uranium until World War II, and depleted uranium from the 1950s until 1972. Depleted uranium is uranium that contains less than 0.3% of the fissile isotope ^{235}U (vs a natural abundance of about 0.7%), and is obtained as a byproduct of producing enriched uranium for use in non-Canadian nuclear reactors and in nuclear weapons. The most common isotope of uranium, whether in natural or in depleted uranium, is ^{238}U.

(a) ^{238}U is an alpha emitter. Write a balanced equation for this reaction.

(b) The half-life of ^{238}U is 4.468×10^{9} y. Convert this value to seconds. Use 1 y = 365.25 d.

(c) What is the rate constant for the alpha decay of ^{238}U?

(d) A uranium-glazed plate contains approximately 3.5 g of uranium. Assuming it's all ^{238}U (isotopic mass: 238.050 7882 u), how many **atoms** of ^{238}U does the plate contain?

(e) What is the radioactivity (in Bq, i.e. counts per second) of the uranium-glazed plate described in part (d)?

(f) Over a year, a dishwasher handling these plates in a restaurant might be exposed to 6×10^{9} alpha particles, each with an energy of 6.836×10^{-13} J. If the dishwasher weighs 85 kg, what is the absorbed dose over a year?

(g) For alpha particles, the relative biological effectiveness (RBE) is 20. What is the equivalent dose, in Sv, per year for the dishwasher? (For comparison, workers outside of the nuclear industry are limited to occupational exposures of less than 1 mSv per year.)

(h) Eating off of uranium-glazed plates on a regular basis is thought to be particularly damaging. Why is eating off of these plates more dangerous than simply handling them?