

Introductory Astronomy

Homework 10: Solar System Formation Not to be handed in. Homework solutions are posted already.

1. We will probably never be able to understand how our solar system formed in exact detail, but can understand in more general terms how it formed by relying on various kinds of evidence: e.g.,
 - a) star formation regions that we observe, extrasolar planets (of which **111** are known as of 2004mar04), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **DINOSAUR FOSSILS**.
 - b) star formation regions that we observe, extrasolar planets (of which **1111** are known as of 2004mar04), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **BIOLOGY**.
 - c) star formation regions that we observe, extrasolar planets (of which **111** are known as of 200mar04), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
 - d) star formation regions that we observe, extrasolar planets (of which **2** are known as of 2004mar04), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
 - e) star formation regions that we observe, extrasolar planets (of which **111** are known as of 2004mar04), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **WISHFUL THINKING**.

2. “Let’s play *Jeopardy!* For \$100, the answer is: This principle (i.e., which is really a guiding hypothesis) explains coincidences in physics and in the universe that are favorable to life by stating that without these coincidences we would not be here to observe the universe. The opposite point of view is that such coincidences were dictated by the strict physical necessity of some underlying theory of everything. Of course, if the second view is correct, one wonders why the theory of everything in itself happens to be compatible with life (i.e., be biophilic).”

What is the _____ Principle, Alex?

- a) Anthropic b) Copernican c) Cosmological d) Biophilic e) Peter

3. “Let’s play *Jeopardy!* For \$100, the answer is: He/She was the first proposer of the nebular hypothesis for the origin of the solar system in the context of Newtonian physics.”

Who was _____, Alex?

- a) composer Johann Sebastian Bach (1685–1750) b) adventurer and writer Giovanni Jacopo Casanova (1725–1798) c) astronomer Caroline Herschel (1750–1848) d) English general and statesman John Churchill, Duke of Marlborough (1650–1722) e) philosopher Immanuel Kant (1724–1804)

4. Radioactive dating:

- a) uses radioactive decay to determine age.
- b) uses radioactive decay to determine mass.
- c) is useless in practice.
- d) uses radioactive decay to determine the half-life of a radioactive nuclear species (i.e., a radioactive nuclide).
- e) sounds more exciting than it is.

5. A half-life is:
- the time it takes for **HALF** a sample of a radioactive species (i.e., a radioactive nuclide) to decay to a daughter nuclide.
 - the time it takes for a **QUARTER** of a sample of a radioactive nuclear species (i.e., a radioactive nuclide) to decay to a daughter nuclide.
 - the time between star and planet formation.
 - the age of the Sun.
 - the nuclear fuel burning life-time of the Sun.
6. You have a sample of rock in which the ratio of ^{40}K (radioactive potassium) to ^{40}Ca (stable calcium) is 1 to 1. The half-life of ^{40}K is about 1.3 billion years. Assuming the rock was calcium-free at formation, what is the approximate time since the rock was formed?
- 1.3 billion years.
 - 2.6 billion years.
 - Only a few years at most.
 - 13 billion years.
 - 4.6 billion years.
7. A sample was initially pure radioactive ^{238}U (an isotope of uranium). The half-life of ^{238}U is 4.5 billion years. Currently, only 1/128 of the sample is ^{238}U . How old is the sample?
- 4.5 billion years old.
 - 4.5 million years old.
 - 31.5 billion years old. This is older than the currently estimated age of the universe $\sim 10\text{--}20$ billion years old. Clearly there is an inconsistency.
 - 35 billion years old. This is older than the currently estimated age of the universe $\sim 10\text{--}20$ billion years old. Clearly there is an inconsistency.
 - 15 billion years old. This age puts a lower limit on the age of the universe (i.e., the time since the Big Bang).
8. In dense environments, decay energy from radioactive decay is usually converted into:
- macroscopic kinetic energy.
 - thermal (or heat) energy.
 - macroscopic gravitational potential energy.
 - macroscopic magnetic field energy.
 - reindeer energy.
9. The planets orbit approximately in a single plane probably because:
- the early solar nebular magnetic field forced them to form in a plane.
 - pure luck.
 - pure bad luck.
 - they formed out the disk of material that formed about the proto-Sun.
 - a passing star pulled them into a plane long after formation.
10. Volatiles could not condense much in the inner solar system, and thus did not get incorporated in massive amounts into the inner planets. But the Sun is mainly hydrogen and helium which are certainly volatiles. Why in the Sun and not in the inner planets?
- Because of the Sun's magnetic field.
 - The proto-Sun grew massive enough to hold its volatiles by **GRAVITATION** despite the high temperature it reached.
 - The proto-Sun grew massive enough to hold its volatiles by the **PRESSURE FORCE** despite the high temperature it reached.
 - The hydrogen and helium that went into the Sun was sticky.
 - The difference has no plausible explanation.

11. The solar wind probably flushed much of the primordial gas and dust out of the solar system during its formation. Say that the solar wind has a speed of 400 km/s. Pluto is about 40 astronomical units from the Sun and the astronomical unit is about 1.5×10^{13} cm. How long does it take the wind to travel from the Sun to Pluto? About:
- a) 1.5×10^7 s or half a year. b) 1.5×10^7 s or 10 years. c) 1.5×10^{13} s. d) 1×10^5 s or a day. e) 1×10^5 s or 10 day.
12. The planetary formation sequence as currently understood is:
- a) collective-self-gravitation/sticky accretion of gas to grains, condensation of grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
- b) collective-self-gravitation/sticky accretion of gas to grains, condensation of grains to planetesimals, second round of sticky accretion of planetesimals to protoplanets.
- c) condensation of gas to grains, collective-self-gravitation/sticky accretion of grains to planetesimals, further sticky accretion of planetesimals to protoplanets.
- d) condensation of gas to grains, collective-self-gravitation/sticky accretion of grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
- e) gravitational coalescence of gas to grains, collective-self-gravitation/sticky accretion of grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
13. Two planetesimals are most likely to totally bind together if:
- a) they are moving toward each other at high relative speed for a head-on collision.
- b) they are moving directly away from each other.
- c) they are at very different distances from the star or protostar.
- d) they are invisible.
- e) they approach each other with low relative velocity.
14. What is the origin of the helium in the Sun's atmosphere, in the Sun's core, and in Jupiter?
- a) The helium in the Sun's atmosphere and Jupiter is **PRIMORDIAL**: i.e., it was the helium present when the solar system formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars. The helium in Sun's core is partially primordial and partially from the **NUCLEAR BURNING** of the hydrogen that goes on in the Sun's core.
- b) All this helium is **PRIMORDIAL**: i.e., it was the helium present when the solar system formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars.
- c) All the helium in the solar system was formed in the **SUN'S CORE** by the nuclear burning of helium. Convection transported this helium to the surface of the Sun and the solar wind transported some of it into the outer solar system where of it got accreted onto the proto-Jupiter.
- d) All the helium in the solar system was formed by nuclear burning of hydrogen that occurred **WHERE THE HELIUM IS NOW FOUND**. Thus, there was nuclear burning on the surface of the Sun and in Jupiter in the early days of the solar system. Of course, nowadays the nuclear burning of hydrogen occurs only in the Sun's core.
- e) The chemical breakup of **PRIMORDIAL WATER** (i.e., water that existed before the solar system formed) left the helium in all of these sites.
15. "Let's play *Jeopardy!* For \$100, the answer is: These solar system bodies are thought to form according to one of two possible theories. Theory 1: they start as rocky/icy protoplanets that are massive enough to gravitationally attract and hold abundant hydrogen and helium gas. Theory 2: they start as gravitationally collapsed dense cores of hydrogen and helium just as stars do and grow by further gravitational accretion of abundant hydrogen and helium."

What are _____, Alex?

- a) gas giant or Jovian planets
- b) rocky or terrestrial planets
- c) minor planets or an asteroids
- d) Kuiper Belt objects or a trans-Neptunian objects
- e) mirror matter planets

16. Asteroids are:

- a) very probably leftover icy planetesimals (or planetesimal fragments) from the formation of the solar system. Some have undergone internal-heat geological evolution.
- b) very probably leftover gaseous planetesimals (or planetesimal fragments) from the formation of the solar system.
- c) very probably leftover rocky planetesimals (or planetesimal fragments) from the formation of the solar system. Some have undergone internal-heat geological evolution.
- d) icy planetesimals that formed outside of the solar system. Some have undergone internal-heat geological evolution.
- e) rocky planetesimals that formed outside of the solar system. Some have undergone internal-heat geological evolution.

17. Comets are:

- a) very probably leftover **ICY/CARBONACEOUS** planetesimals (or planetesimal fragments) from the formation of the solar system.
- b) very probably leftover **ROCKY** planetesimals (or planetesimal fragments) from the formation of the solar system.
- c) very probably leftover **GASEOUS** planetesimals (or planetesimal fragments) from the formation of the solar system.
- d) **ICY/CARBONACEOUS** planetesimals that formed outside of the solar system.
- e) **ROCKY** planetesimals that formed outside of the solar system.

18. Both gravitational collapse and collisions tend to cause

- a) cooling. The heat from the bodies gets transformed into bulk kinetic energy and gravitational potential energy.
- b) plate tectonics.
- c) heating. The gravitational potential energy and bulk kinetic energy of the bodies gets randomized into microscopic kinetic energy.
- d) plate tectonics. The gravitational potential energy and bulk kinetic energy of the bodies sets up convective flows which brings magma to the surface of the protostars. The magma pushes about the crustal plates.
- e) magnetic fields which then cause the bodies to explode apart.

19. In one kind of analysis, the evolution of rocky/icy bodies in the solar system has been divided in to four stages. Not all rocky/icy bodies will go through all stages. These stages in probable time order are:

- a) nuclear differentiation, heavy bombardment, flooding by liquid nitrogen and/or liquid helium, and plate tectonics.
- b) nuclear differentiation, light bombardment, flooding by liquid nitrogen and/or water, and plate tectonics.
- c) nuclear differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
- d) chemical differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
- e) chemical differentiation, heavy bombardment, flooding by lava and/or water, and continuing geologic evolution.

20. Mainly by studying the variations in lunar crater density per unit area and the variations in ages of rocks from the lunar highlands and maria, solar system astrophysicists have concluded that there was a period of heavy bombardment by various solar system bodies. This heavy bombardment:
- a) was about 65 million years ago.
 - b) was about 100 to 65 million years ago.
 - c) covered about the first billion years of the solar system after formation.
 - d) was about 15 to 10 billion years ago.
 - e) was coincident with the last ice age.
21. Why is almost every solar system body with a **SOLID** surface scarred by craters?
- a) In the **10 BILLION YEARS** since the solar system formed there has been a continuous increasing bombardment on solar system bodies by other solar system bodies that was heaviest at early times in the heavy bombardment phase of the solar system. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
 - b) In the **4.6 BILLION YEARS** since the solar system formed there has been a continuous bombardment on solar system bodies by other solar system bodies that was heaviest at early times in the heavy bombardment phase of the solar system. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
 - c) The heaviest bombardment of solar system bodies by other solar system bodies has occurred in the last **100 MILLION YEARS**. This bombardment has cratered almost all the solid surfaces. It has also probably been responsible for the dinosaur extinction circa 65 million years ago. The likely deep impact of kilometer-scale asteroid 1997 XF₁₁ on Earth in 2028 is just part of this bombardment phase.
 - d) Most solid bodies in the solar system have suffered heavy continuous volcanism: the asteroids most of all. The craters are mostly volcanic, not impact, in origin.
 - e) The Earth isn't scarred by craters.
22. The rocky bodies in the solar system from the largest asteroids upward in mass probably all experienced to some degree geological activity caused by:
- a) internal heat from formation and past and in some cases current radioactive decay heating.
 - b) liquid water erosion.
 - c) hydrogen embrittlement.
 - d) internal heat from the red giant phase of the Sun.
 - e) ice ages.