Astronomy 102A: 3rd Exam NAME:
2005 April 14 Thursday

Instructions: There are 50 multiple-choice questions and the test is out of 50 marks. Choose the **BEST** answer, completion, etc., and darken fully the appropriate circle on the **TABLE** provided on page 2. Read all responses carefully. **NOTE** that long, detailed responses won't depend on hidden keywords: keywords in such responses are **BOLD-FACED** capitalized.

This is a **CLOSED-BOOK** exam. **NO** cheat sheets allowed. Calculators are permitted. This a 75 minute exam. Remember your name (and write it down on the exam too). **DO NOT** discuss the test with those in any section who have not taken it.

You must show a photo id when handing in the exam.

NAME:

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	26.	O	O	O	O	O
2.	O	O	O	O	O	27.	O	O	O	O	O
3.	O	O	O	O	O	28.	O	O	O	O	O
4.	O	O	O	O	O	29.	O	O	O	O	O
5.	O	O	O	O	O	30.	O	O	O	O	O
6.	O	O	O	O	O	31.	O	O	O	O	O
7.	O	O	O	O	O	32.	O	O	O	O	O
8.	O	O	O	O	O	33.	O	O	O	O	O
9.	O	O	O	O	O	34.	O	O	O	O	O
10.	O	O	O	O	O	35.	O	O	O	O	O
11.	O	O	O	O	O	36.	O	O	O	O	O
12.	O	O	O	O	O	37.	O	O	O	O	O
13.	O	O	O	O	O	38.	O	O	O	O	O
14.	O	O	O	O	O	39.	O	O	O	O	O
15.	O	O	O	O	O	40.	O	O	O	O	O
16.	O	O	O	O	O	41.	O	O	O	O	O
17.	O	O	O	O	O	42.	O	O	O	O	O
18.	O	O	O	O	O	43.	O	O	O	O	O
19.	O	O	O	O	O	44.	O	O	O	O	O
20.	O	O	O	O	O	45.	O	O	O	O	O
21.	O	O	O	O	O	46.	O	O	O	O	O
22.	O	O	O	O	O	47.	O	O	O	O	O
23.	O	O	O	O	O	48.	O	O	O	O	O
24.	O	O	O	O	O	49.	O	O	O	O	O
25.	O	O	O	O	O	50.	O	O	O	O	O

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040 qmult 00100 1 4 3 easy deducto-memory: life history of Sun

Extra keywords: Sunlife

1. The life history of our own star, the Sun, is known to us by:

   a) direct observations of all of its stages.
   b) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
   c) direct observations of its current stage plus observations of other stars in all their stages and modeling.
   d) modeling alone.
   e) sheer guesswork.

   SUGGESTED ANSWER: (c) We only directly observe the Sun in its current stage: i.e., the middle main sequence stage. The Sun has been there all of human history and will be there all of foreseeable human history.

   Wrong answers:
   e) "Sheer" and "guesswork" are correctly spelt anyway.

   Redaction: Jeffery, 2001jan01

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040 qmult 00210 1 1 4 easy memory: interstellar medium (ISM) defined 2

Extra keywords: CK-299,321, Sunlife

2. Gas and dust in the space inside galaxies is:

   a) made of antimatter. b) completely negligible for all purposes. c) the intergalactic medium (GSM). d) the interstellar medium (ISM). e) completely invisible.

   SUGGESTED ANSWER: (d)

   Wrong answers:
   e) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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040 qmult 00330 2 1 5 moderate memory: molecular cloud composition

Extra keywords: CK-300, Sunlife

3. The composition of molecular clouds in the interstellar medium is dominated by:

   a) carbon dioxide. b) molecular oxygen only. c) helium gas only. d) amino acids. e) molecular hydrogen gas and helium gas.

   SUGGESTED ANSWER: (e) Hydrogen and helium dominate the composition of the universe and a molecular cloud should have molecules. Zeilik p. 332 confirms that the hydrogen in molecular clouds is molecular hydrogen.

   Wrong answers:
   a) Carbon dioxide is an important tracer of molecular clouds, but it is a minority species.

Redaction: Jeffery, 2001jan01

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040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife

4. A protostar is sometimes conveniently defined to be a:

   a) star that can no longer burn hydrogen to produce heat energy.
   b) white dwarf.
   c) dense core of gas contracting to become a star that is hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
   d) molecular cloud that will become a star.
   e) giant molecular cloud that will become a star.

SUGGESTED ANSWER: (c) Se-222, gives this definition and FK-450 implicitly agrees. He calls the protostar a prestellar object, but that seems too convoluted for me. But the term is used loosely in astronomy I think.

Wrong answers:
e) A white dwarf is at the far end of stellar evolution.

Redaction: Jeffery, 2001jan01

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040 qmult 01000 1 4 1 easy deducto memory: H II region defined
Extra keywords: CK-307,321,322-3

5. Star formation in giant molecular clouds often results in the formation of OB associations: collections of hot, bright OB stars that ionize the surrounding molecular cloud and evaporate dust because of their strong ultraviolet emission. The gas region ionized by an OB associations is called a/an:

   a) H II region. b) small molecular cloud. c) a black hole. d) a dark cloud. e) He region.

SUGGESTED ANSWER: (a)

Wrong answers:
b) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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040 qmult 01500 1 4 3 easy deducto-memory: disk defined
Extra keywords: Sunlife

6. "Let's play *Jeopardy*! For $100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles: the material goes around some large astro-body in nearly circular orbits of varying radii in the same direction."

   What are _____, Alex?

   a) CDs b) planets c) disks d) satellites e) projectiles

SUGGESTED ANSWER: (c)

Wrong answers:

a) Compact disks are disks, but not the right kind of disk.

Redaction: Jeffery, 2001jan01

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040 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency
Extra keywords: CK-304, Sunlife

7. Disk formation is:

a) a unique event that happened only in the case of the formation of the Sun.
b) a common event in star formation as far as astronomers can tell.
c) a process in nuclear burning.
d) never observed in star formation.
e) responsible for the heating up of the protostar.

SUGGESTED ANSWER: (b)

Wrong answers:
d) It has been observed.

Redaction: Jeffery, 2001jan01

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041 qmult 01010 1 1 4 easy memory: main sequence longest phase
Extra keywords: CK-322-6, Sun-question, Sunlife

8. Most nuclear-burning stars are main sequence stars. The reason for this is that the main sequence phase of the nuclear-burning life of star of any mass is the:

a) shortest phase. b) most popular phase. c) wettest phase. d) longest phase. e) darnest phase.

SUGGESTED ANSWER: (d) See CK-311

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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041 qmult 01020 2 4 2 moderate deducto-memory: main sequence brightening
Extra keywords: Sun-question, Sunlife

9. As a **MAIN SEQUENCE STAR** ages, its luminosity (i.e., total energy output):

a) decreases. b) increases. c) oscillates wildly. d) becomes tangential. e) incinerates.

SUGGESTED ANSWER: (b) See Se-246.

Wrong answers:
a) As the fuel is being exhausted this seems reasonable. But in fact the fuel burns more rapidly as it is expended.
d) A nonsense answer.
e) Luminosity is a characteristic of a substance, not a substance itself: the verb incinerate cannot apply to luminosity.

Redaction: Jeffery, 2001jan01

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042 qmult 00110 2 4 4 moderate deducto-memory: post-main sequence of Sun
Extra keywords: Sunlife

10. After the end of its main sequence lifetime, the Sun will probably go through the following phases in order:

    a) red giant, helium flash (a very short stage), horizontal branch star, green giant, cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
    b) red giant, helium flash (a very short stage), horizontal branch star, jolly green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
    c) red giant, helium flash (a very short stage), vertical branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
    d) red giant, helium flash (a very short stage), horizontal branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
    e) red giant, Larry, Curly, Moe, black dwarf (very far in the future).

SUGGESTED ANSWER: (d) See Se-250–252 and Sh-152. Note only stars in the 0.4–3 $M_\odot$ range have a helium flash.

Wrong answers:
e) Larry, Curly, Moe—you get it—Larry, Curly, ...

Redaction: Jeffery, 2001jan01

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041 qmult 01030 2 4 4 mod. deducto-memory: early Sun luminosity
Extra keywords: Sun-question, Sunlife

11. At the time the Sun first became a main sequence star, its luminosity was probably _____ than at present.

    a) 30 % greater b) 100 % greater c) 50 times greater d) 30 % lower
    e) 100 % lower

SUGGESTED ANSWER: (d)

Wrong answers:
e) Now this doesn't seem very likely does it.

Redaction: Jeffery, 2001jan01

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042 qmult 00410 1 4 3 easy deducto-memory: AGB Sun vaporizes Earth
Extra keywords: Sunlife

12. If in its AGB (asymptotic red giant) phase (or 2nd red giant phase), the Sun has expanded and enveloped the Earth, the Earth will:

    a) very quickly collapse to a black hole.
    b) become a red giant star.

c) spiral into the deeper layers of the Sun because of the drag forces of the Sun's outer layers. There the Earth will be totally vaporized. "So the glory of this world passes away": *Sic transit gloria mundi.*
d) gain escape velocity and be ejected from the solar system because of the drag forces of the Sun's outer layers.
e) implode to form a protostar.

SUGGESTED ANSWER: (c) Zeilik p. 359 gives the Earth only about 200 years of survival after envelopment.

I once carried on a conversation in Latin: "E pluribus unum", "tempus fugit", "natura nonsaltum", "O tempores, O mores", "in vino veritas".

Wrong answers:
a) We havn't discussed black holes, but I don't think this answer would seem plausible compared to the others.
b) This is what the Sun is doing, not the Earth.
d) Drag forces slow down, they don't accelerate. They always oppose motion.
e) The Earth is much too small to become a protostar and why would it do this.

Redaction: Jeffery, 2001jan01

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042 qmult 00600 1 4 4 easy deducto-memory: planetary nebula defined
Extra keywords: CK-329,346 FK-493, Sunlife

13. A planetary nebula is:

a) a cloudy **planet**.
b) a cloud that will coalesce into a **planet**.
c) a shell of gas thrown off by a dying star before it becomes a **protostar**.
d) a shell of gas thrown off by a dying star before it becomes a **white dwarf**.
e) a shell of gas thrown off by a dying star before it becomes a **galaxy**.

SUGGESTED ANSWER: (d)

Wrong answers:
a) This answer should be really out of it.

Redaction: Jeffery, 2001jan01

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043 qmult 00100 1 4 1 easy deducto-memory: white dwarf defined
Extra keywords: CK-346,347-5, Sunlife

14. White dwarfs are:

a) the compact remnants of stars. They are **NOT** burning nuclear fuel. They are **COOLING DOWN** forever.
b) giant red stars.
c) the compact remnants of stars. They are **STILL** burning nuclear fuel.
d) the compact remnants of stars. They are **NOT** burning nuclear fuel. But they are **HEATING UP** forever.

e) the compact remnants of stars. They are **NOT** burning nuclear fuel. They have **NEVER** been observed: they are merely predicted theoretically.

SUGGESTED ANSWER: (a)

Wrong answers:
e) They have to been observed.

Redaction: Jeffery, 2001jan01

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043 qmult 00310 1 4 5 easy deducto-memory: black dwarfs do not exist
Extra keywords: Sunlife

15. "Let's play *Jeopardy*! For $100, the answer is: If the Big Bang Theory of the universe and our theory of star evolution are correct, then these star remnants do **NOT** currently exist but will some billions of years or more in the future."

What are _____, Alex?

a) golden bears b) planets c) red giants d) white dwarfs e) black dwarfs

SUGGESTED ANSWER: (e)

Wrong answers:
a) It's been a long time since Jack Nicklaus dominated the golf scene.
b) Just checking to see if you are awake.

Redaction: Jeffery, 2001jan01

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020 qmult 00090 1 4 3 easy memory: evidence of solar system formation

16. 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**.

SUGGESTED ANSWER: (c)

Wrong answers:
e) If only wishful thinking actually worked.

Redaction: Jeffery, 2001jan01

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020 qmult 00095 1 4 1 easy deducto-memory: Anthropic principle

17. "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

SUGGESTED ANSWER: (a)

Wrong answers:
b) This principle is that we Earthlings occupy an ordinary place in the universe.
c) This principle is the hypothesis that the universe is homogeneous and isotropic when one considers the average behavior of large enough regions. As far as we can observe this hypothesis is confirmed by observations, but the large regions have to be very large: i.e., of order 100 Mpc and the observable universe only has a radius of order 4300 Mpc.
d) This is not a standard term, but may be what should be used in place of the Anthropic Principle.
e) Back in the 1970's this fellow named Peter wrote a popular book called *The Peter Principle* in which he demonstrated that people tended to be promoted to their level of incompetence. As a predictive theory it is pretty feeble stuff, but one can always find victims of it. It was sort of like pet rocks—don't ask.

Redaction: Jeffery, 2001jan01

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020 qmult 00097 2 4 5 moderate deducto-memory: Kant's nebular hypothesis

18. "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)

SUGGESTED ANSWER: (e)

Wrong answers:

a) Da, da, da, da. No that was Beethoven.
b) I don't think Casanova had any mathematical interests, but he did obtain a doctorate of laws from the University of Padua: unfortunately, no record of this degree has been found.
c) She was a comet hunter and a helpmeet (eek!!!) to her brother William Herschel the leading observational astronomer of the 18th century.
d) An ancestor of Winston Churchill: "He never walked off a battle field save as a victor; he never beseiged a place he did not take."

Redaction: Jeffery, 2001jan01

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020 qmult 00110 2 5 3 moderate thinking: radioactive dating, half-life

19. Radioactive dating of a rock gives the:

a) age of the radioactive nuclei in the rock.
b) time since the rock was last exposed to sunlight.
c) time since the rock was formed provided the pre-formation daughter element abundance **CAN** be distinguished the post-formation daughter element abundance.
d) time since the rock was formed even when the pre-formation daughter element abundance **CANNOT** be distinguished the post-formation daughter element abundance.
e) time since the rock was last exposed to radioactivity.

SUGGESTED ANSWER: (c) I probably didn't talk about this in class. One has to read the book and use some understanding too. Note Ze-158 confirms that the technique is called radioactive dating.

Wrong answers:

a) Students wouldn't know this, but nuclei of the same element are essentially identical in quantum theory. They don't have the degrees of freedom to be individually characterized. Decay is a random process: a radioactive nuclei formed a second ago and one formed 10 Gyrs ago have exactly the same probability of decay in theory. The ages of individual nuclei cannot be determined by internal means in principle. But this answer can be ruled out since it means that radioactive dating doesn't give the age of the rock.
c) A red herring and it wouldn't give the rock's age.
d) if the radioactive nuclear species (i.e., radioactive nuclides) in the rock and their daughter product nuclides from an earlier existence were mixed together at the time of formation, then simple comparison of the ratio of radioactive element and daughter element abundance wouldn't give the age of the rock.
e) But this wouldn't give the rock's age.

Redaction: Jeffery, 2001jan01

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020 qmult 00400 1 3 1 easy math: radioactive dating, half-life U-238

20. A sample is initially pure radioactive $^{238}_{92}$U (an isotope of uranium). After four half-lives how much $^{238}_{92}$U is left?

    a) 1/16. b) 1/2. c) 1/4. d) 1/10. e) None.

SUGGESTED ANSWER: (a) People do need to remember what half-life means. For the half-life of $^{238}_{92}$U see Enge-225.

Wrong answers:

e) Formally this only happens at infinite time for the ideal case of an infinite sample. But in fact for a finite sample many half-lives along you will reach a point where the formula predicts a fraction of an undecayed nucleus remaining. At that point the last nucleus is gone or will be in a finite (though perhaps) very long time.

Redaction: Jeffery, 2001jan01

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020 qmult 00610 1 4 2 easy deducto-memory: decay energy conversion

21. In dense environments, decay energy from radioactive decay is usually converted into:

    a) macroscopic kinetic energy. b) heat energy. c) macroscopic gravitational potential energy. d) macroscopic magnetic field energy. e) reindeer energy.

SUGGESTED ANSWER: (b)

Wrong answers:

e) This is the Christmas answer.

Redaction: Jeffery, 2001jan01

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020 qmult 00810 1 1 4 easy memory: planets form out of a proplyd

22. The planets orbit approximately in a single plane probably because:

    a) the early solar nebular magnetic field forced them to form in a plane.
    b) pure luck.
    c) pure bad luck.
    d) they formed out the disk of material that formed about the proto-Sun.
    e) a passing star pulled them into a plane long after formation.

SUGGESTED ANSWER: (d)

Wrong answers:

e) This theory had a vogue once in the early decades of the 20th cnetury, but now is out of date.

Redaction: Jeffery, 2001jan01

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020 qmult 00900 2 5 2 moderate thinking: Sun's volatiles

23. 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?

    a) Because of the Sun's magnetic field.
    b) The proto-Sun grew massive enough to hold its volatiles by **GRAVITATION** despite the high temperature it reached.
    c) The proto-Sun grew massive enough to hold its volatiles by the **PRESSURE FORCE** despite the high temperature it reached.
    d) The hydrogen and helium that went into the Sun was sticky.
    e) The difference has no plausible explanation.

    SUGGESTED ANSWER: (b)

    Wrong answers:
    c) The pressure force is trying to push matter out of the Sun.

    Redaction: Jeffery, 2001jan01

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020 qmult 01100 1 4 2 easy deducto-memory: planetesimals

24. Planetesimals are:

    a) objects of kilometer size or greater that are always lost from the solar system during planet formation.
    b) objects of kilometer size or greater that can mutually accrete (largely because of gravitational attraction) to form protoplanets.
    c) centimeter size grains that mutually accrete (largely because of gravitational attraction) to form protoplanets.
    d) very tiny planets.
    e) always made of ices.

    SUGGESTED ANSWER: (b)

    Wrong answers:
    d) Well not really.

    Redaction: Jeffery, 2001jan01

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020 qmult 01200 2 1 4 moderate memory: planetary formation sequence

25. 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.

SUGGESTED ANSWER: (d) This can be just a straight moderate memory question, but some thought can narrow the answers down. Gravity only plays a role in larger body structure. Gases condense.

Wrong answers:

e) Not condensation of grains to planetesimals.

Redaction: Jeffery, 2001jan01

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020 qmult 01650 1 4 1 easy deducto-memory: gas giant formation

26. "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

SUGGESTED ANSWER: (a)

Wrong answers:

a) Rocky planets do not have abundant hydrogen and helium and no thinks they start forming just like stars.

c) There is a theory–for which there is a shred of evidence even—that there is a mirror universe which interacts with our universe only be gravitation and few minor, obscure processes. In the mirror universe there are mirror planets that our just like ours one supposes.

Redaction: Jeffery, 2001jan01

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020 qmult 01800 1 1 3 easy memory: asteroids

27. 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.

SUGGESTED ANSWER: (c)

Wrong answers:
a) Not icy.

Redaction: Jeffery, 2001jan01

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020 qmult 01900 1 1 3 moderate deduction: heating by collapse and collision
28. 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.

SUGGESTED ANSWER: (c) I've thrown in some thought provoking (I hope) red herrings that could stimulate some thought on the part of the students.

Wrong answers:
d) Magma on protostars!

Redaction: Jeffery, 2001jan01

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020 qmult 02000 1 1 3 easy memory: chemical differentiation
29. In planet formation, the chemical differentiation stage is the stage:

a) of heavy cratering.
b) of heavy cratering and lava flows.
c) where the molten materials of the early planets separated under the action of **GRAVITY**. The **DENSER** materials sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.
d) where the molten materials of the early planets separated under the action of **MAGNETIC FIELDS**. The **DENSER** material sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.
e) where the molten materials of the early planets separated under the action of the **SOLAR WIND**. The **LESS DENSE** material sank to the deeper regions; the **DENSER** materials rose to the upper regions.

SUGGESTED ANSWER: (c) Is the process chemical differentiation. Well the process is physical, not chemical, but on the other hand it is the elements

(to which chemicals is often a synonym) that differentiate. Maybe elemental differentiation is good.

Wrong answers:

e) Not the solar wind.

Redaction: Jeffery, 2001jan01

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020 qmult 02100 2 4 3 moderate deducto-memory: heavy bombardment

30. 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.

SUGGESTED ANSWER: (c) Even if the students can't recall the 4.6–3.8 Gyr ago period discussed in class, they should be able to rule out the other periods just by knowing the bombardment was early and the solar system is about 5 Gyrs old. Of course, if someone is hooked on dinosaurs ... Some of the informations in the preamble comes from FMW-175–176.

Wrong answers:

e) Since we may still be in the last ice age isn't odd that we havn't noticed the heavy bombardment.

Redaction: Jeffery, 2001jan01

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020 qmult 02500 2 4 1 moderate deducto-memory: residual/radioactive geology

31. 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 enbrittlement.
    d) internal heat from the red giant phase of the Sun.
    e) ice ages.

SUGGESTED ANSWER: (a)

Wrong answers:

b) Only Earth and Mars have had much liquid water erosion at least so far as we can tell now. I doubt that liquid water ever existed significantly on the large asteroids.

c) According to a graffito I once read in a washroom stall, hydrogen enbrittlement was the probable reason why the coat hook had broken off.

Personally, I think they make those things off the sludge at the bottom of the vat of chrome. Why not make them out of steel.

e) As far as we know only Earth has had ice ages, but Mars may have had them too.

Redaction: Jeffery, 2001jan01

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021 qmult 00080 1 4 1 easy deducto-memory: gravity and sphere

32. "Let's play *Jeopardy*! For $100, the answer is: This geometrical shape is normal for massive astronomical bodies where gravity and the pressure force dominate the structure."

What is a/an _____, Alex?

a) sphere b) ellipse c) corona d) cone e) snow cone

SUGGESTED ANSWER: (a) Notice I exclude kinetic energy from being dominating. A lot of kinetic energy can result in disk structure like galaxies.

Wrong answers:

e) I can't recall ever having eaten a snow cone: I'm sure I don't want to.

Redaction: Jeffery, 2001jan01

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021 qmult 00300 1 1 1 easy memory: internal structure of Earth

33. Three main ingredients in understanding the internal structure of the Earth are

a) seismology, the primordial solar nebula composition, and modeling.
b) seismology, the primordial solar nebula composition, and biology.
c) seismology, biology, and cryptology.
d) seismology, biology, and cosmetology.
e) the primordial solar nebula composition, extinct marine invertebrates, and undesirable activities.

SUGGESTED ANSWER: (a) Getting the right answer may depend mostly on the reading, not the lectures.

Wrong answers:

b) Biology hasn't really played much of a role.
c) Cryptology is the study of crypts.
d) Oddly cosmology and cosmetics derive from the same Greek kosmos that originally meant an adornment, particularly to beautiful orderliness (Fu-59–60).
e) Well, no.

Redaction: Jeffery, 2001jan01

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021 qmult 00310 1 4 1 easy deducto-memory: central region of Earth

34. The central region of the Earth is believed to be

a) hot and composed mainly of solid iron. b) cold and composed mainly of solid iron. c) hot and composed of gold. d) cold and composed of

uranium. e) hot and composed of uranium.

SUGGESTED ANSWER: (a) Solid iron with substantial amounts of nickel and sulfur (FMW-149).

Wrong answers:
c) There's gold in them there core.

Redaction: Jeffery, 2001jan01

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021 qmult 00400 1 1 3 easy memory: water coverage of Earth
35. Of the Earth's surface, liquid water covers about:

a) 10 %. b) 30 %. c) 71 %. d) 95 %. e) 99 %.

SUGGESTED ANSWER: (c) An easy memory question from general knowledge if not from the book. Even from remembering what a globe looks like the answer can be deduced. Col-38 says 70.8 % covered by water.

Wrong answers:
e) We'd all be Taihitian then.

Redaction: Jeffery, 2001jan01

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021 qmult 00450 2 4 2 moderate deducto-memory: crust composition
36. The composition of the Earth's crust is dominated by:

a) oxygen (O) and uranium (U) in about a 1 to 1 ratio by mass.
b) oxygen (O) and silicon (Si) in about a 2 to 1 ratio by mass.
c) oxygen (O) and iron (Fe) in about a 1 to 1 ratio by mass.
d) oxygen (O) and hydrogen (H) in about an 8 to 1 ratio by mass.
e) argon (Ar) and kryptonite (Ke) in about a 3 to 2 ratio by mass.

SUGGESTED ANSWER: (b) Silicates are mostly SiO_2 (silica) which is not a molecule but simply a compound that forms in different crystal arrangements. The atomic mass of Si is about 28 and of O is about 16. Evidently, the crust is a bit more rich in O than the SiO_2 formula suggests.

Wrong answers:
a) The surface isn't that radioactive.
c) No the crust is not mostly rust which also has hydrogen in it.
d) No the crust is not mostly water either in liquid or solid form.
e) Kryptonite! Superman beware.

Redaction: Jeffery, 2001jan01

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021 qmult 00512 2 4 2 moderate deducto-memory: Earth's surface warmth
37. The surface of the Earth is mainly kept warm by:

a) geothermal heat from the interior.
b) electromagnetic radiation from the Sun.
c) radioactive decay heat from radioactive isotopes on the surface.

d) natural natural gas fires in near-surface caves.
e) artificial natural gas fires in near-surface caves.

SUGGESTED ANSWER: (b) The mean solar heat flux to the Earth's surface is about 700 W/m**2/4 and the geothermal heat flux is only 0.008 W/m**2 (CW-46). I'm not sure about the 1/4: the text I'm relying on isn't entirely clear.

Wrong answers:
a) Geothermal heat is vital to geology, but it doesn't keep most of the surface warm.
d) The first "natural" is an adjective modifying "natural gas fires." There is no "natural natural gas" that I know of.

Redaction: Jeffery, 2001jan01

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021 qmult 00520 1 4 2 easy deducto-memory: crustal plates
38. The Earth's surface is divided into crustal plates. The plates:

a) have been fixed and unchanging since the Earth formed.
b) are pushed around and renewed by geological activity.
c) are heavily scarred by impact craters.
d) float directly on a sea of molten iron and nickel.
e) are pushed around and renewed by geological activity. The temperature of their upper surfaces is over 1000 K due to heat flow from the interior.

SUGGESTED ANSWER: (b)

Wrong answers:
e) We live on the surface of plates. They arn't that hot.

Redaction: Jeffery, 2001jan01

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021 qmult 00600 1 4 4 easy deducto-memory: plate tectonics driver
39. Plate tectonics is driven by:

a) magnetic fields. b) the solar wind. c) comet impacts. d) convective heat flow in the mantle. e) convective heat flow in the atmosphere.

SUGGESTED ANSWER: (d)

Wrong answers:
c) Not very likely is it.

Redaction: Jeffery, 2001jan01

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021 qmult 00610 1 4 3 easy deducto-memory: Earth resurfacing
40. If the solar system formed about 4.6 billion years ago, why are Earth rocks mostly younger than one billion years old?

a) Impacts by young asteroids have resurfaced the Earth.
b) The solar wind has rejuvenated Earth rock.

c) Internal-heat-driven geological activity and erosion have continually renewed most of Earth's surface rocks.
d) Internal-heat-driven geological activity and erosion have renewed once only most of Earth's surface rocks.
e) The Earth formed only within the last billion years.

SUGGESTED ANSWER: (c) See Lissauer 1993, ARA&A, 31, 129, p. 132 for typical Earth rock ages.

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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021 qmult 00710 1 4 1 easy deducto-memory: tectonic plate boundaries

41. Most tectonic plate boundaries are under the ocean, but a few cross land: e.g.,

a) across Iceland (the Mid-Atlantic Ridge) and southern California from the Gulf of California to about San Francisco (the San Andreas Fault).
b) across Iceland (the Mid-Pacific Ridge) and southern California from the Gulf of California to about San Francisco (the San Fernando Fault).
c) across Nevada (the Las Vegas Wash) and northern California from San Francisco to the Klamath River Valley (the Sonoma Fault).
d) across Nevada (the Las Vegas Wash Basin) and northern California from San Francisco to the Klamath River Valley (the Sonoma Default).
e) across Nevada (the Mifault) and northern California from San Francisco to the Klamath River Valley (the Yurfault).

SUGGESTED ANSWER: (a)

Wrong answers:
e) Mifault, yurfault—ha, ha, ha, good one eh.

Redaction: Jeffery, 2001jan01

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021 qmult 01110 1 4 2 easy deducto-memory: Pangaea

42. In the Permian period about 250 million years ago, the Earth is believed to have had one large super-continent called:

a) Panama. b) Pangaea. c) Pangloss. d) Pan-Am. e) Panic.

SUGGESTED ANSWER: (b) WB-92 says 300 to 250 million years ago and other sources say 225 million years ago. Obviously some discussion is going on. It was a long time ago anyway.

Wrong answers:
c) Candide's tutor, Dr. Pangloss: "This is the best of all possible worlds."

Redaction: Jeffery, 2001jan01

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021 qmult 01200 2 4 2 moderate deducto-memory: Earth atmosphere gases

43. The three most abundant gases by mass in the present-day Earth atmosphere (excepting water vapor which varies in abundance) are:

a) molecular nitrogen (N_2), molecular oxygen (O_2), and carbon dioxide (CO_2).
b) molecular nitrogen (N_2), molecular oxygen (O_2), and argon (Ar) which is a monatomic noble gas.
c) molecular nitrogen (N_2), molecular oxygen (O_2), and ozone (O_3).
d) molecular oxygen (O_2), carbon dioxide (CO_2), and molecular hydrogen (H_2).
e) molecular oxygen (O_2), carbon dioxide (CO_2), and helium (H) which is a monatomic noble gas.

SUGGESTED ANSWER: (b) See Se-439, CW-296, and Cox-258, but note Cox has got the wrong exponents for some numbers.

Wrong answers:
a) The Earth would be warm if there were as much carbon dioxide as argon, of course, the answer doesn't imply that there is.

Redaction: Jeffery, 2001jan01

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021 qmult 01210 1 4 5 easy deducto-memory: trace gas carbon dioxide

44. "Let's play *Jeopardy*! For $100, the answer is: This gas is a trace gas in the present-day Earth atmosphere, but its importance for the biosphere both in photosynthesis and as a greenhouse gas is immense."

What is _____, Alex?

a) molecular oxygen (O_2) b) helium (H) c) ozone (O_3) d) argon (Ar) e) carbon dioxide (CO_2)

SUGGESTED ANSWER: (e)

Wrong answers:
a) Oxygen gas is a product of photosynthesis and I believe plants do need it for respiration, but it is not an important greenhouse gas it seems (SWT-507).
d) Argon is 1.29 % by mass and is the 3rd most abundant gas in the atmosphere. But Argon is a noble gas and is chemically almost completely inert.

Redaction: Jeffery, 2001jan01

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021 qmult 01500 1 1 3 easy memory: O_2 for breathing

45. For respiration we need:

a) oxygen in any compound whatever. b) carbon monoxide (CO). c) molecular oxygen (O_2). d) krypton gas. e) neon gas.

SUGGESTED ANSWER: (c)

Wrong answers:
a) I don't think we could breathe atomic oxygen. It's a highly reactive gas, but probably in the wrong way. In any case, its molecular oxygen (O_2) that we breathe.

b) Carbon monoxide is toxic. See Keenan, p. 181.
d) Krypton is an inert gas. Maybe bad for Superman.
e) Neon is an inert gas.

Redaction: Jeffery, 2001jan01

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021 qmult 01800 1 5 1 easy thinking: greenhouse effect defined
46. The greenhouse effect is explained as follows:

a) The solar radiation peaks in the **VISUAL** and the Earth's atmosphere is comparatively transparent in the visual. Thus a lot of solar radiation reaches the Earth's surface where much of it is absorbed: this heats the surface. The surface radiates **INFRARED (IR) RADIATION** to which the atmosphere is fairly opaque. An overall balance between energy absorbed and radiated from the Earth must be achieved in order to keep the Earth's mean temperature constant. Thus in order to keep the rate of energy outflow sufficiently high, the Earth surface temperature is higher than it would be in the absence of the high IR opacity (absorption) of the atmosphere. (**HIGHER** temperature differences between hot and cold regions cause faster heat flows from the hot to the cold region. Most of space is effectively cold in that it does not radiate a lot of energy.) The **INCREASE** of the mean Earth temperature caused by the comparatively high IR opacity of the atmosphere is the greenhouse effect.
b) The solar radiation peaks in the **INFRARED (IR)** and the Earth's atmosphere is comparatively transparent in the IR. Thus a lot of solar radiation reaches the Earth's surface where much of it is absorbed: this heats the surface. The surface radiates **RADIO RADIATION** to which the atmosphere is fairly opaque. An overall balance between energy absorbed and radiated from the Earth must be achieved in order to keep the Earth's mean temperature constant. Thus in order to keep the rate of energy outflow sufficiently high, the Earth surface temperature is higher than it would be in the absence of the high IR opacity (absorption) of the atmosphere. (**LOWER** temperature differences between hot and cold regions cause faster heat flows from the hot to the cold region. Most of space is effectively cold in that it does not radiate a lot of energy.) The **DECREASE** of the mean Earth temperature caused by the comparatively high radio opacity of the atmosphere is the greenhouse effect.
c) The construction of a large number of greenhouses since the early 19th century has increased the amount of carbon dioxide in the atmosphere and in theory this is slowly choking all plant life on Earth. This choking problem is the greenhouse effect.
d) The construction of a large number of greenhouses since the early 19th century resulted from the English craze for **TROPICAL FLOWERS,** particularly orchids. The greenhouse fad is colloquially called the greenhouse effect.
e) Greenhouses release excessive amounts of molecular oxygen into the atmosphere. Molecular oxygen is a highly reactive compound. In excessive concentrations, it is very dangerous to living tissue. The release of molecular oxygen by greenhouses is the greenhouse effect.

SUGGESTED ANSWER: (a) Even on general knowledge answer (a) should

be deduceable. The point of the question is really to give a succinct and correct (to the best of my understanding) account of the greenhouse effect for the benefit of the students.

The greenhouse effect is a partial misnomer. The effect as described does play a secondary role in heating greenhouses–the glass windows acting as the atmosphere—but the main heating effect is that cooling upward convection can't happen in a confined building. See "Greenhouse: How Do Greenhouses Work?" by Sue Ann Bowling.

`http://www.gi.alaska.edu/ScienceForum/ASF8/817.html .`

Wrong answers:

b) Everyone knows the greenhouse effect heats, not cools.

d) Is this true about the orchids?

Redaction: Jeffery, 2001jan01

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021 qmult 02000 1 4 4 easy deducto-memory: heat flow direction

47. Given a temperature difference and insulation between two bodies, the rate of heat flow between these two bodies increases with _____ temperature difference and _____ insulation.

a) decreasing; with increasing b) increasing; with increasing c) decreasing; with decreasing d) increasing; with decreasing e) increasing; is unaffected by

SUGGESTED ANSWER: (d) Everyone knows insulation decreases heat flow. Most everyone should guess, increasing temperature difference increases heat flow.

Wrong answers:

a) Exactly wrong.

Redaction: Jeffery, 2001jan01

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021 qmult 02200 1 3 1 easy math: increasing CO_2

48. From about 1960 to 2000, the Earth's atmosphere CO_2 content increased from about 315 ppm (parts per million) to about 370 ppm. Assuming the rate of increase is constant, in about what year will the content be 800 ppm? (Of course, constant increase is unlikely. There are several trends, some of them certainly varying, acting to increase and decrease CO_2 content.) Wally Broecker of Lamont-Doherty Earth Observatory and winner of the 12th Nevada Medal in 1998 or 1999 (for science I suppose though nothing on the Nevada Medal lecture notice says so) suggests the possibility—only possibility mind—that a catastrophic change in global climate could occur over a few decades when the content crosses the 700–800 ppm threshold.

a) 2300. b) 2200. c) 2100. d) 2050. e) 2010!!!

SUGGESTED ANSWER: (a)

The rate of increase averaged over 40 years is

$$\frac{55}{40} = 1.375 \approx 1.4 \qquad \text{ppm per year .}$$

Thus, to increase by another 430 ppm requires

$$\frac{430}{1.4} = 307 \approx 300 \qquad \text{years} .$$

Actually, the rate increase for the last few years (circa 2004) the rate has been about 1.8 ppm per year and in 2003 the content increased by 3 ppm. The rate of increase could go higher still as countries around the world increase their use of carbon fuels. But, one hopes, that we stop releasing carbon dioxide to the atmosphere.

Wrong answers:
e) Now wouldn't this be lovely.

Redaction: Jeffery, 2001jan01

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021 qmult 00510 2 4 3 moderate deducto-memory: lithosphere defined
49. The upper rigid layer of the Earth is called the _____ and it is of order _____ kilometers deep.

a) lithenosphere; 6000 b) lithosphere; 6000 c) lithosphere; 100
d) asthenosphere; 100 e) lithenosphere; 100

SUGGESTED ANSWER: (c) See Se-433.

Wrong answers:
d) The asthenosphere is the plastic lower mantle. It is the region below the lithosphere

Redaction: Jeffery, 2001jan01

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021 qmult 03000 2 4 3 moderate deducto-memory: Earth's permanent atmosphere
50. In the most current understanding, what is the source of the Earth's original permanent atmosphere and its water? The source is:

a) gravitational accumulation of gases directly from the solar nebula.
b) the giant impact that caused the Moon's formation.
c) outgassing from rock caused by internal-heat-driven geological activity and possibly comet impacts. Recent evidence (circa 1999), however, from Comet Hale-Bopp suggests comets may **NOT** have been important contributors.
d) biological activity.
e) the solar wind and comets. Recent evidence (circa 1999), however, from Comet Hale-Bopp suggests comets may **NOT** have been important contributors.

SUGGESTED ANSWER: (c) Note this question avoids the primeval-secondary atmosphere question that Seeds discusses.

In a sense, the atmosphere is always coming into being and always passing away, and *a fortiori* this was more true of the early atmosphere when outgassing, comet impacts, and escape to space probably happened much more furiously than at present: "This is my grandfather's axe: my father replaced the axe head; I've replaced the haft."

Wrong answers:

a) this answer is not the right one for the "permanent" atmosphere. It may be the source for an early atmosphere of gases. See Se-420.

b) a red herring.

d) biological activity certainly has modified the "permament" atmosphere creating oxygen, but it wasn't the original source.

e) the solar wind is actually thought to be the cause of extremely weak atmospheres on Mercury and the Moon, but not on Earth. The part about Comet Hale-Bopp is correct, however.

Redaction: Jeffery, 2001jan01