Conceptual Physics NAME:

Homework 2a: Matter Homeworks are due usually a day after the corresponding textbook part/lecture is completed. Due dates will be announced in class. Multiple-choice problems will all be marked. **USE** the answer table for these problems. The rest of the homeworks will be marked for apparent completeness and some full-answer problems will/may be marked in detail. Make the full-answer solutions sufficiently detailed that the grader can follow your reasoning. Solutions will be posted eventually after the due dates. The solutions are intended to be (but not necessarily are) super-perfect and often go beyond full answers. For an argument or discussion problem, there really is no single right answer. The instructor's answer reflects his long experience in physics, but there could be objections to his arguments, assumptions, nuances, style, facts, etc.

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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003 qmult 00100 1 4 3 easy deducto-memory: birth of natural philosophy

1. "Let's play *Jeopardy*! For $100, the answer is: The of natural philosophy—the explanation of nature in terms of general principles or axiom instead of mythological anthropomorphic dieties—began circa ____________ by the earlier Greek philosophers (the Presocratics). It should be said that the distinction between natural philosophy and and mythology is not altogether clearcut Many mythologies begin with rather impersonal dieties who are rather like forces or elements of nature."

   What is ____________, Alex?

   a) 3000 BCE b) 1000 BCE c) 600 BCE d) 250 BCE e) 150 CE

   SUGGESTED ANSWER: (c)

   Wrong answers:
   a) The dawn of writing in Mesopotamian and Egypt.
   b) Roughly the start of the iron age and in Greece the middle of the Greek Dark Age.
   d) Arguably the high point of the Greek Golden age of natural philosophy.
   e) The flourishing of Ptolemy, one the last great Greek natural philosophers.

   Redaction: Jeffery, 2012jan01

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003 qmult 00110 1 1 4 easy memory: founders of atomism

2. Atomism was introduced by the Greek Presocratic philosophers Leucippus (first half of 5th century BCE) and Democritus (c. 460–c. 370 BCE) and incorporated into the philosophy of ____________. The later Latin poet Lucretius (c. 99–c. 55 BCE) gave a famous exposition of atomism in his poem *De Rerum Natura* (*On the Nature of Things*). The association of atomism with atheism led to a certain degree of dislike for atheism by other philosophical schools in Greco-Roman antiquity. Actually, the atomists were not atheists—they just believe the gods did not interfere in the world—slacker gods.

   a) Socraties (c. 469–399 BCE) b) Plato (c. 425–c. 348 BCE) c) Aristotle (384–322 BCE) d) Epicurus (341–270 BCE) e) Zeno (c. 334–c. 262 BCE)

   SUGGESTED ANSWER: (d)

   Wrong answers:
   b) He would have retched at the idea.

   Redaction: Jeffery, 2012jan01

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003 qmult 00120 1 1 4 easy memory: atomism revived in 17th century

3. Atomism, invented in Greco-Roman antiquity, was never forgotten and in the 17th century (in the Scientific Revolution), it was revived, mostly importantly by René Descartes (1596–1650) and ____________. The ideas about atomism by the 17th century atomists were useful important in stimulating scientific advances, but the 17th century atomists failed to make atomism a convincing scientific theory: i.e., a theory that made exact predictions that were testable and thereby made atomism falsifiable. The great authority achieved by ____________ probably helped to keep atomism in mind during the 18th century.

   a) Thomas Harriot (1560–1621) b) Galileo (1564–1642) c) Jeremiah Horrocks (1618–1641) d) Isaac Newton (1643–1727) e) Edmond Halley (1656–1742)

   SUGGESTED ANSWER: (d)

   Wrong answers:
   a) A Renaissance scientist who'd be a lot better known if he had ever published his discoveries.
   c) A brilliant fellow who alas died very young. If he'd lived longer he might have given Newton a run for his money.

   Redaction: Jeffery, 2012jan01

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003 qmult 00130 1 4 2 easy deducto-memory: John Dalton

4. "Let's play *Jeopardy*! For $100, the answer is: His theory of that atoms of each type of element had definite masses and that atoms combined in definite ratios to make compounds explained by compounds are always made of definite ratios by mass of the elements that make them up."

Whos is ____________, Alex?

a) Antoine Lavoisier (1743–1794) b) John Dalton (1766-1844)
c) Thomas Young (1773–1829 d) Humphrey Davy (1778–1829)
e) Michael Faraday (1791–1867)

SUGGESTED ANSWER: (b)

Wrong answers:
a) One of the leading founders of modern chemistry, but that didn't save him from guillotine—"The people have no need of savants."
c) Did lots of things in science, but not chemistry it seems.
d) Another chemical innovator and the patron of Michael Faraday. Also a poet.
e) A chemist, but also the inventor of the electric generator.

Redaction: Jeffery, 2012jan01

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003 qmult 00140 1 4 4 easy deducto-memory: J. J. Thomson and electron

5. "Let's play *Jeopardy*! For $100, the answer is: He and his colleagues in 1896 concluded that the electron was particle of definite mass and charge although they could only measure the charge-to-mass ratio accurately. The electron was present in all types of matter and eventually it was concluded that it was probably subatomic: i.e., a constituent of all atoms."

Who is ____________, Alex?

a) Michael Faraday (1791–1867) b) Johann Christian Poggendorff (1796–1877)
c) George FitzGerald (1851–1901) d) J.J. Thomson (1856–1940)
e) Ernest Rutherford (1871–1937)

SUGGESTED ANSWER: (d)

Wrong answers:
b) Poggendorff. Good old Poggendorff. Old Poggendorff—inventor of potentiometer.
c) Irish physicist who revived the term electron for Thomson's particle—FitzGerald's uncle George Stoney (1826–1911) invented the word earlier for the fundamental unit of electric charge.
e) Discovered the nucleus in 1911.

Redaction: Jeffery, 2012jan01

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003 qmult 00160 1 1 1 easy memory: Bohr atom wrong

6. The ____________ proposed in 1913 has some correct features. It posits quantized atomic energy states for electrons with the electrons in motion about an atomic nucleus. The electrons have angular momentum. It requires that photons can only be absorbed or emitted on transitions between the quantized states. However, the ____________ is essentially wrong. In particular, it cannot be generalized to atoms of more than one electron. So it is important historically and pedagogically, but not otherwise.

a) Bohr atom b) plum pudding atom c) Rutherford atom d) round atom
e) cubic atom

SUGGESTED ANSWER: (a)

Wrong answers:
e) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00200 1 1 3 easy memory: quantum mechanics

7. Discovered in 1925–1926, ____________ is the correct microscopic physics insofar as we know. It has never been found to be wrong and it has been extensively verified in pure science and in technology. Your cellphone would not work if it were not correct. There are, of course, mistakes in calculations and experiments. There are also many approximations in applications of ____________. Finding solutions from ____________ any real system (including atoms) involves many approximations and in many cases only crude solutions can be found. Advanced mathematical techniques and the use of supercomputers have extended the range of exact solutions. It must be mentioned that ____________ also presents mysteries that despite decades of study remain unsolved.

a) fluid dynamics b) classical mechanics c) quantum mechanics d) thermodynamics
e) acoustics

SUGGESTED ANSWER: (c)

Wrong answers:
e) Oh, c'mon.

Redaction: Jeffery, 2012jan01

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003 qmult 00210 1 1 3 easy memory: modern theory of atoms

8. The modern theory of atoms is based on quantum mechanics. In this theory, the atom consists of tiny central nucleus and swarm of electrons which surround the nucleus. An electron does not exist in a single position. It is in a continuum superposition of positions simultaneously. Only quantized energy states exist for the electrons, most with angular momentum, but some without. The overall state of the electrons is described by a ____________ (usually symbolized by Greek captial letter Ψ) which among other things gives the probability density for finding (or measuring) an electron at any point in space.

   Atoms have no sharp edges. The ____________ formally goes to zero only at infinity relative to the nucleus. However, in fact the ____________ is negligibly different from zero at only a few angstroms ($1\,\text{Å} = 10^{-10}\,\text{m}$) from the nucleus. Various kinds of mean or characteristic radii are used to characterize the effective size of atoms.

   It is rather difficult to picture atoms because of the complex spatial behavior of the ____________. Schematic representations that only reveal certain aspects are useful. The old chemistry textbook images of atoms as spheres that can overlap to form molecules are pretty useful. Actual images of atoms taken with modern techniques only reveal limited views of their structure, and so do not at all give the perfect way of pictureing atoms.

   a) potential b) particle function c) wave function d) splash function e) probability

SUGGESTED ANSWER: (c)

Wrong answers:
e) Plausible, but not what we call the thing.

Redaction: Jeffery, 2012jan01

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003 qmult 00220 1 1 1 easy memory: atomic and nuclear size scale

9. The size scale of an atom is ____________ and the size scale of a nucleus is ____________.

   a) $1\,\text{Å} = 10^{-10}\,\text{m}$; $1\,\text{fermi} = 10^{-15}\,\text{m}$ b) $1\,\text{Å} = 10^{-8}\,\text{m}$; $1\,\text{fermi} = 10^{-13}\,\text{m}$
   c) $1\,\text{Å} = 10^{-6}\,\text{m}$; $1\,\text{fermi} = 10^{-7}\,\text{m}$ d) $1\,\text{Å} = 10^{-3}\,\text{m}$; $1\,\text{fermi} = 10^{-4}\,\text{m}$
   e) $1\,\text{Å} = 10^{-15}\,\text{m}$; $1\,\text{fermi} = 10^{-20}\,\text{m}$

SUGGESTED ANSWER: (a)

Wrong answers:
b) Right if one wrote centemiters rather than meters.

Redaction: Jeffery, 2012jan01

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003 qmult 00230 1 1 3 easy memory: atomic mass range

10. Atomic mass is measured in the atomic mass unit (abbrevation AMU with symbol u or the obsolete amu). Often the unit symbol u is not written explicitly: it is understood. The modern definition of the AMU is

$$1\,\text{u} = \frac{1}{12}(\text{mass of a unperturbed ground-state carbon-12 atom} .$$

The ground state of a system is its lowest energy state. It is not possible to have an exactly unperturbed ground state, but one get arbitrarily close to it in principle and in practice so close that it is the best way to define a mass standard by far. Why carbon-12? Oh some good experimental reason. Maybe its just the easiest atom to make measurements with. Protons and neutrons are both slightly heavier than an AMU. The range of atomic masses is:

   a) ~ 0.1–$2500\,\text{u}$. b) ~ 0.1–$250\,\text{u}$. c) ~ 1–$250\,\text{u}$. d) ~ 4–$400\,\text{u}$. e) ~ 4–$40\,\text{u}$.

SUGGESTED ANSWER: (c)

Wrong answers:
a) How can an atom be less massive than proton.

Redaction: Jeffery, 2012jan01

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003 qmult 00232 1 1 3 easy memory: Avogadro's number and moles

11. The atomic mass unit in grams is given by

$$1\,\mathrm{u} = 1.660538921(73) \times 10^{-24}\,\mathrm{g}$$

where the number in parenthesis is, as usual, the uncertainty in the last digits of the number. The AMU is only approximately known in grams though it is known to high accuracy. In the not so distant future, the gram may be defined as exactly so many AMUs. The number of AMUs in a gram is Avogadro's number or 1 mole:

$$N_A = \frac{1\,\mathrm{g}}{1.660538921(73) \times 10^{-24}\,\mathrm{g}} = 6.02214179(30)10^{23} \ .$$

The number of atoms in any sample of mass m of an element of atomic mass A is

$$N = \frac{m}{A\,\mathrm{u}} = \left(\frac{m}{A \times 1\,\mathrm{g}}\right)(1\,\mathrm{g} \times 1\,\mathrm{u}) = \left(\frac{m}{A \times 1\,\mathrm{g}}\right) N_A \ .$$

In moles, the sample is

$$\frac{N}{N_A} = \frac{m}{A \times 1\,\mathrm{g}} \ .$$

One mole of an element has mass $A \times 1\,\mathrm{g}$ (usually just written A) which is called the element's:

a) atomic mass. b) atomic weight. c) gram atomic mass. d) gram glen atomic mass.
e) grammatical atomic mass.

SUGGESTED ANSWER: (c)

Wrong answers:
d) I wonder where my old friend Graham Glen is these days.

Redaction: Jeffery, 2012jan01

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003 qmult 00236 1 1 1 easy memory: H2O moles

12. Hydrogen has an atomic mass of about 1 and oxygen of about 16. About how many moles of water molecules are there in 9 g of water?

a) 1/2. b) 1. c) 18. d) 9. e) −2.

SUGGESTED ANSWER: (a)

Wrong answers:
b) Not the worst of all possible guesses.
e) The worst of all possible guesses.

Redaction: Jeffery, 2012jan01

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003 qmult 00250 1 1 5 easy memory: empty atom

13. Atoms are sometimes described as mostly empty. But this is inexact. They have a low density spherical or nearly spherical region occupied by electrons and a high density ____________ occupied by protons and neutrons.

a) zone b) chromosome c) core d) valence shell e) nucleus

SUGGESTED ANSWER: (e)

Wrong answers:
a) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00252 1 1 5 easy memory: density of an atom

14. Given that an atom mass is of order an AMU ($1\,\text{u} = 1.660538921(73) \times 10^{-24}\,\text{g}$) and the atom radius is of order 1 Å, what is the order of atomic density?

a) $10\,\text{g/cm}^{14}$. b) $10^3\,\text{g/cm}^3$. c) $100\,\text{g/cm}^3$. d) $10\,\text{g/cm}^3$. e) $1\,\text{g/cm}^3$.

SUGGESTED ANSWER: (e)

Behold:

$$\rho = \frac{1\,\text{u}}{(1\,\text{Å})^3} \approx \frac{10^{-24}\,\text{g}}{10^{-24}\,\text{cm}^3} = 1\,\text{g/cm}^3 \ .$$

This is the density of water and of order the density of all ordinary solids and liquids under Earth-atmosphere-like pressures. Thus we know that ordinary solids and liquids have the atoms tightly packed: they are essentially touching. In gases which are usually much less dense, the atoms or molecules are mostly not strongly interacting and only interact during collisions.

Wrong answers:
a) This is of order nuclear density

Redaction: Jeffery, 2012jan01

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003 qmult 00254 1 1 1 easy memory: density of a nucleus
15. Given that an atomic nucleus mass is of order an AMU ($1\,\text{u} = 1.660538921(73) \times 10^{-24}\,\text{g}$) and the nuclear radius is of order 1 fermi $= 10^{-13}$ cm, what is the order of nuclear density?

a) $10^{15}\,\text{g/cm}^3$. b) $10^3\,\text{g/cm}^3$. c) $100\,\text{g/cm}^3$. d) $10\,\text{g/cm}^3$. e) $1\,\text{g/cm}^3$.

SUGGESTED ANSWER: (a)

Behold:

$$\rho = \frac{1\,\text{u}}{(1\,\text{fermi})^3} \approx \frac{10^{-24}\,\text{g}}{10^{-39}\,\text{cm}^3} = 10^{15}\,\text{g/cm}^3 \ .$$

Wikipedia gives $4 \times 10^{14}\,\text{g/cm}^3$ as about average for nuclear density. For macroscopic matter samples, nuclear density is only reached in neutron stars and some other extreme astrophysical environments.

Wrong answers:
a) This is of order nuclear density

Redaction: Jeffery, 2012jan01

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003 qmult 00270 1 1 4 easy memory: identical atoms
16. Atoms of the same type (meaning same element and isotope) are ____________ in their properties. This result follows from quantum mechanics the most trusted of all physical theories. It means among other things that there is no way to tell whether an atom is young or old. In fact, atoms of the same type lose their identities when their wave functions overlap. There is no way in theory to tell which was which during the overlap phase or afterward. Perhaps, one could say that atoms of given type at a given time were partially caused by atoms of that type at earlier times. But that is just to awkward for anyone.

a) elaborate b) indistinct c) distinct d) identical e) ghostly

SUGGESTED ANSWER: (d)

Wrong answers:
c) Exactly wrong.

Redaction: Jeffery, 2012jan01

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003 qmult 00300 1 1 3 easy memory: elementary unit of charge e
17. The elementary unit of charge is

$$e = 1.602176565(35) \times 10^{-19}\,\text{C} \ .$$

where C stands for coulomb, the macroscopic unit of charge. Insofar as we can tell, the charge a proton is exactly e, the charge of a neutron is exactly 0, and the charge of an electron is exactly:

a) e. b) 0. c) $-e$. d) $(1/3)e$. e) $(2/3)e$.

SUGGESTED ANSWER: (c)

Wrong answers:

d) Quarks and antiquarks have charges $\pm(1/3)e$ and $\pm(2/3)e$, but they are not isolatable particles it seems and by historical convention and for convenience one still refers to e as the elementary unit of charge.

Redaction: Jeffery, 2012jan01

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003 qmult 00300 1 1 1 easy memory: likes repel, unlikes attract

18. Like charges ____________ and unlike charges ____________.

a) repel; attract b) repel; repel c) attract; repel d) attract; attract
e) are non-interacting; attract

SUGGESTED ANSWER: (a)

Wrong answers:

c) Exactly wrong.

Redaction: Jeffery, 2012jan01

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003 qmult 00310 1 1 1 easy memory: nearly neutral universe

19. On all size scales above the atomic size scale, the universe is usually ____________. This because insofar as we can tell the universe has equal amounts of positive and negative charge and because of the nature of the electric force and charged particles. Of course, net charge buildups of various sizes do occur, but this because something overcomes the neutralizing tendency.

a) nearly neutral b) exactly neutral c) positive d) negative
e) both positive and negative

SUGGESTED ANSWER: (a)

Wrong answers:

e) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00320 1 1 3 easy memory: strong force bind nuclei

20. The nuclear strong force bonds the protons in the ____________ against their mutual electric force repulsion. The nuclear strong force is thus a very strong force. But is very short range acting between nucleons (i.e., protons and neutrons) over distances of order 1 $rmfermi10^{-15}$ m. Thus, in ordinary terrestrial environments nuclei are mutually repelled and do not react with each other. The nuclei must be given high kinetic energy in order ram close enough to one another for nuclear reactions to occur.

a) atom b) molecule c) nucleus d) chromosome e) photon

SUGGESTED ANSWER: (c)

Wrong answers:

e) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00320 1 1 5 easy memory: no collapse of atom because of QM

21. The short answer why the electrons of atoms don't just collapse into the nucleus is that ____________ forbids. Thus, there is no neutralization at the atomic or smaller scales. Actually, electrons and protons do react to create neutrons and that process goes on all the time in nature, but in most environments at a very low rate.

a) statics b) dynamics c) electromagnetism d) classical mechanics
e) quantum mechanics

SUGGESTED ANSWER: (e)

Wrong answers:
d) Exactly wrong.

Redaction: Jeffery, 2012jan01

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003 qmult 00330 1 1 2 easy memory: nucleus described a bit

22. For nuclear force reasons, all stable nuclei and virtually unstable nuclei must have both protons and neutrons, except for the ordinary hydrogen nucleus which consists of a single proton. (The common name for proton and neutron is nucleon.) The number of protons in the nucleus is the atomic number Z, the number of neutrons is neutron number N, and the number of nucleons $(Z+N)$ is the atomic mass number A. There is some confusion since the symbol A is also used for the atomic mass (which is not an integer) which is not the same as atomic mass number although they are usually pretty close. The proton and neutron have approximately an atomic mass unit of mass (and this makes atomic mass number and atomic mass pretty close), but they are both a bit more massive than the AMU: the neutron is slightly more massive than the proton. Also when protons and neutrons are bonded together some mass is lost due to lost binding energy. Recall $E=mc^2$. If energy is lost in binding, mass is lost. For example, helium-4 is 0.7 % less massive than two isolated proton plus two isolated neutrons. Stable nuclei have $N \gtrsim Z$ with N tending to get relatively larger as Z increases.

    The atomic number determines the chemistry of the atom since it fixes the number of electrons in the ____________.

    a) nucleus b) neutral atom c) molecule d) solid e) liquid

SUGGESTED ANSWER: (b)

Wrong answers:
d) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00340 1 1 3 easy memory: decay and half-life

23. Some nuclei are stable. They will last forever unless some force acts on them. Most nuclei are unstable (i.e., radioactive). They will spontaneously decay (i.e., change) into another nucleus (or in alpha-decay or fission) into multiple nuclei. (Most nuclei in type are unstable. In actual population of all nuclei, most nuclei are stable.)

    The decay process is random. A radioactive nucleus may decay in an instant or in unlimited time in the future. But they is no way to tell from nucleus when it will decay. All nuclei of a given type are identical in their properties. There is, however, a sort of characteristic lifetime for an unstable nucleus called a ____________. For a given sample of a radioactive nuclei, half will have decayed after one ____________ on average. Thus, every ____________, the population of a radioactive nuclei decreases by half on average. For example after 10 ____________, only $1/2^{10}=1/1024$ of the original number are left on average. Note the word "average". In any actual case, there are fluctuations from average that grow relatively small as the sample size increases. So the fact that the average number of survivors is not an integer in general is not a problem. If the average survivor number is less then 1, it just means that in some cases there are zero survivor number is zero and in others it is 1 or more.

    a) period/periods b) quarter-life/quarter-lives c) half-life/half-lives
    d) whole-life/whole-lives e) mean lifetime/mean lifetimes

SUGGESTED ANSWER: (c)

Wrong answers:
e) The mean lifetime is actually half-life divided by $\ln(2)=0.6931\ldots$.

Redaction: Jeffery, 2012jan01

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003 qmult 00344 1 1 4 easy memory: half-life probability

24. Say you have a radioactive nucleus with half-life $t_{1/2}$. You've observed it for n half-lives. What is the probability that it will decay in the next half-life? **HINT:** Think about tossing coins.

    a) 1. b) 0. c) $1-1/2^{n+1}$. d) $1/2$. e) $1-1/2^n$.

SUGGESTED ANSWER: (d)

It's like flipping a coin. It doesn't matter how many heads you had in a row, you still have only a 50 % chance of tail on the next throw. In principle, you could go on flipping a coin all day and only get heads Statistically unlikely, but it could happen In fact, it has. Tom Stoppard reports that *Rosencrantz and Guildenstern are Dead* that Rosencrantz and Guildenstern played coin flips and Rosencrantz won on heads 92 times in row. This caused Guildenstern to wonder if Rosencrantz was cheating—or that the universe was.

Wrong answers:
c) A specious answer.

Redaction: Jeffery, 2008jan01

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003 qmult 00346 1 1 3 easy memory: radioactive sample after n half-lives 2

25. Say you had a pure sample of radioactive material at time zero. After n half-lives the fraction of the sample that is still the radioactive material is:

a) 1/2. b) 2. c) $1/2^n$. d) $1/2^{n-1}$. e) $1/2^{n+1}$.

SUGGESTED ANSWER: (c)

Wrong answers:
b) A nonsense answer.

Redaction: Jeffery, 2008jan01

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003 qmult 00348 1 1 5 easy memory: radioactive decay paradox

26. A sample of radioactive material decreases by 1/2 in one half-life in the sense that half of the radioactive nuclei decay to daughter radioactive nuclei in that time. But nuclei are discrete. Now most initial samples of radioactive nuclei will not consist of an exact power of 2. Thus, in general the predicted number of nuclei after any number of half-lives will not be a whole number, but will be some decimal number with a non-zero decimal fraction. Most dramatically at some point predicted number of nuclei will be less than 1. But nuclei are discrete. There is paradox: the number of nuclei are descrete, but the half-life decay rule predicts non-whole numbers of nuclei. The resolution of the paradox is:

a) the half-life rule is just crude approximation.
b) the half-life rule is an excellent approximation for **LARGE** samples that can be treated as consisting of continuous number of nuclei, but fails for fails for **SMALL** numbers of nuclei.
c) the half-life rule is an excellent approximation for **SMALL** samples that can be treated as consisting of continuous number of nuclei, but fails for fails for **LARGE** numbers of nuclei.
d) that there is no resolution. The whole idea of half-life is a crock.
e) the half-life rule makes an average prediction. For example, if you started with a set of many samples of radioactive nuclei, the average number of nuclei for a sample in the set after n half-lives would be predicted by the half-life decay rule. Average numbers of discrete items don't have to be discrete: e.g., the average American family proverbially has 2.3 children—but there is no 0.3 of child out there.

SUGGESTED ANSWER: (e)

Wrong answers:
d) Tempting.

Redaction: Jeffery, 2008jan01

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003 qmult 00350 1 1 2 easy memory: isotopes

27. Atoms of the same atomic number, but different neutron number are __________ of each other. __________ are nearly chemically identical. The __________ of a particular atom is specified by giving the atom name followed by a hyphen and the __________ atomic mass number: e.g., carbon-12 for the carbon atom with 6 neutrons. The difference in mass of __________ does affect reactions slightly and difference in nucleus may very slightly affect electronic structure. However, __________ are quite distinct in nuclear reactions. Generally, there are only a few stable or no stable __________ per element. All elements beyond lead in atomic number have no stable __________ although some __________ of these elements have half-lives of billions years. Some elements have only one stable __________: e.g., beryllium which only has stable __________ beryllium-9. Tin has the most stable

__________, 10. Generally, the further an unstable __________ is in neutron number from stable __________, the more unstable it is: i.e., the shorter its half-life. Some super unstable __________ may have such short half-lives that they are never observed in nature or the lab and only exist in conception.

a) isobar/isobars b) isotope/isotopes c) allotrope/allotropes d) trope/tropes
e) dope/dopes

SUGGESTED ANSWER: (b)

Wrong answers:
d) Figures of speech.

Redaction: Jeffery, 2012jan01

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003 qmult 00352 1 1 1 easy memory: carbon-14 calculation

28. Radioactive carbon-14 decays with a half-life of 5730(40) years. Living creatures acquire carbon-14 from the air: plants get the carbon from the air and animals from eating plants. The fraction of their carbon which is carbon-14 is that of the air at the time that they are living. But after death, no new carbon-14 is acquired and the carbon-14 decays away. By knowing the ratio of the carbon-14 fraction of dead organic material to the fraction of that material when living, you can:

a) calculate the age of the organic material. b) tell nothing.
c) know what organism the material came from. d) tell the cause of death.
e) konw waht ogsinram teh mtraiael cmae form.

SUGGESTED ANSWER: (a)

Wrong answers:
c) Not by just knowing that ratio you can't.
d) Not by just knowing that ratio you can't.
e) Just answer (c) again.

Redaction: Jeffery, 2008jan01

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003 qmult 00354 1 3 1 easy math: radioactive dating/decay K-40

29. You have a sample of rock in which the ratio of ^{40}K (radioactive potassium) to ^{40}Ca (stable calcium-40) 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?

a) 1.3 billion years. b) 2.6 billion years. c) Only a few years at most.
d) 13 billion years. e) 4.6 billion years.

SUGGESTED ANSWER: (a) People do need to remember what half-life means.

Wrong answers:
e) This is the current age of the solar system.

Redaction: Jeffery, 2001jan01

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003 qmult 00356 1 3 1 easy math: radioactive dating, half-life U-238

30. A sample is initially pure radioactive $^{238}_{92}$U (isotope uranium-238). 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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003 qmult 00400 1 1 3 easy memory: element defined and discussed

31. A/An ____________ is a substance made up of only one type of atom as defined by atomic number. A/An ____________ and its constituting type of atom have the same name: e.g., carbon means ____________ carbon and atom carbon. The term ____________ is often used for atoms of its constituting type collectively. For example, one can say this material is 50 ____________ X or atom X. So although ____________ and atom are not formally synonyms, they can be used interchangeably in many contexts. A/An ____________ in solid form can come in different bonding structures called allotropes. For example, carbon can come as graphite (hexagonal array of bonded atoms in layers that are loosely bonded to each other, diamond (tetrahedral bonding repeating without fixed limit), fullerenes (pure carbon molecules), graphene (a single layer of graphite), carbon nanotubes (graphene rolled up into tube), and other forms.

    In nature almost all ____________ have have more than one stable isotope of atom come a mixtures of the isotopes. This is because it is very difficult to separate isotopes of the same ____________ by chemical or other means. (One often says that ____________ cannot be separated into components by chemical means, but this is not strictly true although it is almost always practically true.) The relative isotopic compostion of an lsample is an important clue about its nuclear formation history.

    a) compound/compounds b) mixture/mixtures c) element/elements
    d) Urstoff/Urstoffen e) basic/basics

    SUGGESTED ANSWER: (c)

    Wrong answers:
    d) A German nonsense answer.

    Redaction: Jeffery, 2012jan01

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003 qmult 00410 1 1 2 easy memory: fissionable uranium

32. Uranium in nature comes in 3 isotopes uranium-238 (99.2742 %), uranium-235 (0.7204 %), and uranium-234 (0.0054 %). For fission in nuclear bombs, one needs uranium enriched in uranium-235 (fissionable uranium). The uranium should be 85 % or more uranium-235 for high-grade bombs, though lower amounts will work for less efficient bombs. The stumblingblock in making nuclear bombs has, in fact, always been enrichment in uranium-235 since this cannot be done by ordinary chemical means since uranium-238 and uranium-235 are nearly ____________. Obtaining uranium ore and bomb designs is comparatively not difficult. In fact, it takes a major industrial setup to enrich in uranium-235, and so only nations willing to devote considerable resources to the process have made nuclear weapons. This is a good thing since otherwise nuclear proliferation would probably be unstoppable and nuclear bombs would likely have used many times.

    a) chemically distinct b) chemically identical c) nuclearly identical
    d) nuclearly distinct e) antimatter with respect to each other

    SUGGESTED ANSWER: (b)

    Wrong answers:
    e) A nonsense answer.

    Redaction: Jeffery, 2012jan01

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003 qmult 00420 1 1 2 easy memory: nucleosynthesis

33. The creation of the elements is called nucleosynthesis. In modern theory, most hydrogen and helium and some of lithium, beryllium, and maybe boron were produced in the Big Bang about 13.7 gigayears ago. These are the lightest elements. Then carbon through oxygen are mainly produced in stars and ejected into the interstellar medium by strong stellar winds in late phases of star life. Heavier elements are produced in ____________ or pre-____________ evolution and ejected by the ____________ explosion into the interstellar medium. There are also minor nucleosynthesis sites. Out of the interstellar medium, new generations of stars are formed. The universe is undergoing a continuing enrichment in heavy elements.

    a) moons b) supernovae c) planets d) pulsars e) black holes

    SUGGESTED ANSWER: (b)

Wrong answers:
a) Oh, c'mon.

Redaction: Jeffery, 2012jan01

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003 qmult 00500 1 1 3 easy memory: periodic table

34. The elements/atoms are organized according to their electronic structure (dictated by the electron wave function and which dictates their chemical properties) into the:

 a) secular table. b) aperiodic table. c) periodic table. d) periodic oscillation.
 e) aperiodic chair.

SUGGESTED ANSWER: (c)

Wrong answers:
e) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00510 1 1 3 easy memory: electronic structure and orbitals

35. The wave function of electrons in an atom can be described as consisting of a combination single-particle wave functions called orbitals each of which has specific quantized energy, angular momentum, and spin (which we won't go into). By the Pauli exclusion principle (which is really a quantum mechanics result, not an independent law) only one electron at most can occupy an orbital. The word "occupy" requires considerable qualification that is beyond our scope to go into. In the ground state of an atom (which is where atoms in most environments spend most of their time and which is the main determinant of the atom's chemistry), the electrons occupy the lowests orbitals they can consistent with Pauli exclusion principle. The orbitals themselves are organized into groups called subshells and shells by their energy, angular momentum, and spin quantities. The shells run 1, 2, 3, etc. and each has subshells s, p, d, f, g, etc. in alphabetic order. Only shells up to 7 are needed for all atom ground states. The higher energy an orbital, subshell, or shell, the further out from the nucleus its electrons are on average. Everything would be simple if the subshells and shells filled in there reference order. But it is more complicated than that, and so we have to skirt that difficulty In any case, the outermost electrons, called the valence electrons, actually determine most of the chemistry. It is all rather complicated, but those atoms with full (or closed) s and p subshells on the outside are particularly unreactive and are called noble gases. (Helium is a special case with only two electrons. It is noble gas with only the outermost s subshell filled.) Atoms with one or two more less electrons in the outermost s and p subshells are particularly reactive.

 The electronic structure and chemistry of the atoms is summarized in the ____________. The rows of a ____________ are called periods (or rows) and the columns are called groups (or columns). The elements are entered by increasing atomic number Z going across a row which ends with a noble gas. Then a new row is started. The groups contain elements with similar outer electron structure. and so are somewhat chemically alike in general. But as Z gets higher different kinds of outer electron structure are possible, and so new groups have to be introduced. The 1st row has two groups, the 2nd and 3rd 8 groups, the 4th and 5th rows 18 groups, and the 6th and 7th rows have 32 groups. In order to keep the ____________, to a manageable 18 columns wide, the 14 new groups of the 6th row (the lanthanides) and the 7th row (the actinides) are stuck in footnotes. Currently, the ____________ ends with element 118 which a very unstable laboratory-created element temporarily called ununoctium (Uuo) for one-one-eight. Its chemical properties are unknown, except from theory. It formally falls in group 18, but may not act like noble gas.

 a) secular table. b) aperiodic table. c) periodic table. d) periodic oscillation.
 e) aperiodic chair.

SUGGESTED ANSWER: (c)

Wrong answers:
a) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00600 1 4 4 easy deducto-memory: compound defined

36. "Let's play *Jeopardy*! For $100, the answer is: It is a homogeneous substance made from a combination of two or more elements in which the atom numbers have a definite ratios and definite chemical bonding structure (when in solid form). The physical and chemical properties of the substance are usually quite different from those of the constituent elements."

What is a ____________, Alex?

a) molecule   b) liquid   c) mixture   d) compound   e) solid

SUGGESTED ANSWER: (d)

Wrong answers:

a) As Lurch would say AAAARGH.

Redaction: Jeffery, 2012jan01

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003 qmult 00620 1 1 1 easy memory: molecule defined

37. A ____________ is a group of atoms covalently bonded together with a definite atom number for each kind of atom and a definite bounding structure. Covalent bonds are those in which atoms are bonded by sharing a pair of electrons. An indefinitely largeg structure is not considered a ____________ even if all the bonds are covalent: e.g., diamond which is called a network solid. ____________ can consist of only one atom type like H_2 (molecular hydrogen which is just ordinary hydrogen gas) or O_2 (molecular oxygen which is just ordinary oxygen gas). Such ____________ are not considered to form compounds. ____________ of two or more atom types do form compounds. Many ordinary solids are usually not made of ____________ since the bonding is ionic. For example, sodium chloride (NaCl) consists of alternating sodium and chlorine atoms on a cubic lattice. But there is no special grouping of a sodium atom and chlorine atom: there is no ____________ NaCl. (When sodium chloride melts, the sodium and chlorine atoms are not rigidly bonded to each other.) However, there molecular solids such as water ice (H_2O) and dry ice (solid CO_2).

a) molecule/molecules   b) nano/nanos   c) gas/gases   d) quark/quarks
e) monad/monads

SUGGESTED ANSWER: (a)

Wrong answers:

b) I'm beginning to lose it.

Redaction: Jeffery, 2012jan01

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003 qmult 00700 1 1 3 easy memory: chemical reaction

38. When chemical bonds are changed (formed or broken), one has a:

a) nuclear reaction.   b) solid reaction.   c) chemical reaction.   d) chain reaction.
e) chain-gang reaction.

SUGGESTED ANSWER: (c)

Wrong answers:

e) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00810 1 1 3 easy memory: positron

39. The antiparticle of the electron is the:

a) quark   b) magnitron   c) positron   d) electron itself   e) photon

SUGGESTED ANSWER: (c)

Wrong answers:

b) A nonsense answer.

Redaction: Jeffery, 2012jan01

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003 qmult 00900 1 1 5 easy memory: dark matter

40. Observations of the motions of galaxies and clusters of galaxies tell us that there must be ____________ that we cannot see. Big bang theory tells us that the ____________ cannot be ordinary matter.

a) faint matter b) luminous energy c) dark energy d) luminous matter
e) dark matter

SUGGESTED ANSWER: (e)

Wrong answers:
c) We have this too.

Redaction: Jeffery, 2012jan01

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003 qfull 00130 1 3 0 easy math: Dalton's chemical atom theory

41. Was Dalton's theory about atoms in compounds falsifiable? Discuss.

SUGGESTED ANSWER:

John Dalton (1766–1844) posited that elements consisted of atoms of definite type and mass. When atoms of different elements combined together to form compounds they did so in definite ratios. The ratios reduced to smallest or at least small whole number ratios represented the smallest unit of the compound. These units were somehow bonded together in a definite way out of the constituent atoms. Dalton's theory explained why known compounds were always formed from and broken up into definite relative amounts by mass of the constituent elements. For example, say the smallest unit of compound was made of 2 X atoms of mass m_{X} and 3 Y atoms of mass m_{Y}. The ratio of masses going into the compound would always have to be $2m_{\text{X}}/3m_{\text{Y}}$ no matter how much of the compound was being made.

Dalton's theory of atomic was certainly falsifiable. Having formulated it and determined the relative masses of the elements from some subset of known compounds, he could test that the same relative masses would apply to all known compounds. If they failed to apply, his theory was falsified. He or others could also apply it to new compounds as they were discovered and test if the same relative masses applied. We know the historical answer: Dalton's theory has always passed the tests.

The last conclusion needs some qualification. What history regards as Dalton's essential theory has always passed the tests. But his actual historical theory had some ingredients that have not turned out to be true. For example, atoms of the same chemical type can have different masses: those atoms are isotopes of each other. In Dalton's day, it was probably impossible to have noticed any sign of isotope differences. The fact that certain ingredients of Dalton's atomic theory have been proven to be false is itself at least a partial proof that his theory was falsifiable.

A different point to make about Dalton's theory is that it is not a complete theory of atoms. This is not surprising given Dalton's historical context in the evolution of science. One example, of the limitation of his atomic theory is that it did not include any details about how the atoms actually interacted. Asked to describe his theory's truth, Dalton would probably say something like "the theory may contain essential truths about atoms in chemistry, but it is far from being a complete theory of atoms".

The modern theory of atoms based on quantum mechanics is a much more complete theory. One that is also falsifiable—and has never been falsified.

Redaction: Jeffery, 2012jan01