**Directions: For each question, provide your final answer below the question. For math-based answers, work must be shown on this page or a separate sheet of paper attached to the back of this packet. Without work, no credit will be given. Check significant figures and units.**

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| Isotope | Mass (amu) |
| Ne-20 | 19.99 |
| Ne-22 | 21.99 |

1. Answer the following problems about gases.

(a) The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated in the table.

1. Using the information above, calculate the percent abundance of each isotope.
2. Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon.

(b) A major line in the emission spectrum of neon corresponds to a frequency of 4.34×1014 s-1. Calculate the wavelength, in nanometers, of light that corresponds to this line.

(c) In the upper atmosphere, ozone molecules decompose as they absorb ultraviolet (UV) radiation, as shown by the equation below. Ozone serves to block harmful ultraviolet radiation that comes from the Sun. A molecule of O3(g) absorbs a photon with a frequency of 1.00x1015s-1.

O3*(g)*  O2*(g)* + O*(g)*

1. How much energy, in joules, does the O3*(g)* molecule absorb per photon?
2. The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol-1. Does a photon with a frequency of 1.00×1015 s-1 have enough energy to break this bond? Support your answer with a calculation.

2. Two important concepts that relate to the behavior of electrons in atom systems are the Heisenberg uncertainty principle and the wave-particle duality of matter.

(a) State the Heisenberg uncertainty principle as it related to the determining the position and momentum of an object.

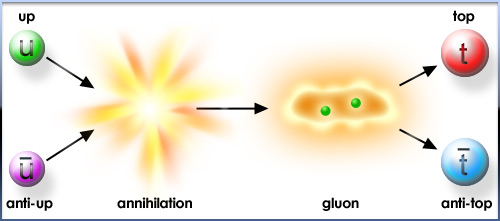
(b) What aspect of the Bohr theory of the atom is considered unsatisfactory as a result of the Heisenberg uncertainty principle?

(c) Explain why the uncertainty principle or the wave nature of particles is not significant when describing the behavior of macroscopic objects, but it is very significant when describing the behavior of electrons.

**Directions: Read the passage below and answer the summary questions that follow in complete sentences.**

**The Particle Adventure**

[www.particleadventure.org](http://www.particleadventure.org)

As you may have read, everything from galaxies to mountains to molecules is made from quarks and leptons. But that is not the whole story. Quarks behave differently than leptons, and for each kind of matter particle there is a corresponding antimatter particle. For every type of matter particle we've found, there also exists a corresponding **antimatter** particle, or **antiparticle**. Antiparticles look and behave just like their corresponding matter particles, except they have opposite charges. For instance, a proton is electrically positive whereas an antiproton is electrically negative. Gravity affects matter and antimatter the same way because gravity is not a charged property and a matter particle has the same mass as its antiparticle. When a matter particle and antimatter particle meet, they annihilate into pure energy!

The idea of antimatter is strange, made all the stranger because the universe appears to be composed entirely of matter. Antimatter seems to go against everything you know about the universe. But you can see evidence for antimatter in this early [bubble chamber](javascript:openpopup('answer_bubble.html');) photo. The [magnetic field](javascript:openpopup('momentum.html');) in this chamber makes negative particles curl left and positive particles curl right. Many electron-positron pairs appear as if from nowhere, but are in fact from photons, which don't leave a trail. Positrons (anti-electrons) behave just like the electrons but curl in the opposite way because they have the opposite charge. If antimatter and matter are exactly equal but opposite, then why is there so much more matter in the universe than antimatter? Well... we don't know. It is a question that keeps physicists up at night. (The usual symbol for an antiparticle is a bar over the corresponding particle symbol. For example, the "up quark" u has an "up antiquark" designated by http://particleadventure.org/images/page-elements/ubar.gif, pronounced u-bar. The antiparticle of a quark is an antiquark, the antiparticle of a proton is an antiproton, and so on. The antielectron is called a positron and is designated e+.)

Quarks are one type of matter particle. Most of the matter we see around us is made from protons and neutrons, which are composed of quarks. There are six quarks, but physicists usually talk about them in terms of three pairs: up/down, charm/strange, and top/bottom. (Also, for each of these quarks, there is a corresponding antiquark.) Be glad that quarks have such silly names -- it makes them easier to remember! Quarks have the unusual characteristic of having a fractional electric charge, unlike the proton and electron, which have integer charges of +1 and -1 respectively. Quarks also carry another type of charge called color charge, which we will discuss later. The most elusive quark, the top quark, was discovered in 1995 after its existence had been theorized for 20 years. Like social elephants, quarks only exist in groups with other quarks and are never found alone. Composite particles made of quarks are called hadrons. Although individual quarks have fractional electrical charges, they combine such that hadrons have a net integer electric charge. Another property of hadrons is that they have no net color charge even though the quarks themselves carry color charge (we will talk more about this later). There are two classes of hadrons:

-Baryons are any hadron which is made of three quarks (qqq). Because they are made of two up quarks and one down quark (uud), protons are baryons. So are neutrons (udd).

-Mesons ...contain one quark (q) and one antiquark (http://particleadventure.org/images/page-elements/qbar.gif).One example of a meson is a pion (http://particleadventure.org/images/page-elements/pi.gif+), which is made of an up quark and a down anitiquark. The antiparticle of a meson just has its quark and antiquark switched, so an antipion (http://particleadventure.org/images/page-elements/pi.gif-) is made of a down quark and an up antiquark. Because a meson consists of a particle and an antiparticle, it is very unstable. The K meson lives much longer than most mesons, which is why it was called "strange" and gave this name to the strange quark, one of its components. A weird thing about hadrons is that only a very very very [small part of the mass of a hadron](javascript:openpopup('hadron_mass.html');) is due to the quarks in it.

The other type of matter particles are the leptons. There are six leptons, three of which have electrical charge and three of which do not. They appear to be point-like particles without internal structure. The best known lepton is the electron (e-). The other two charged leptons are the muon(http://particleadventure.org/images/page-elements/mu.gif) and the tau(http://particleadventure.org/images/page-elements/tau.gif), which are charged like electrons but have a lot more mass. The other leptons are the three types of neutrinos (http://particleadventure.org/images/page-elements/nu.gif). They have no electrical charge, very little mass, and they are very hard to find. Quarks are sociable and only exist in composite particles with other quarks, whereas leptons are solitary particles. Think of the charged leptons as independent cats with associated neutrino fleas, which are very hard to see. For each lepton there is a corresponding antimatter antilepton. Note that the anti-electron has a special name, the "positron."

Neutrinos are, as we've said, a type of lepton. Since they have no electrical or strong charge they almost never interact with any other particles. Most neutrinos pass right through the earth without ever interacting with a single atom of it. Neutrinos are produced in a variety of interactions, especially in particle decays. In fact, it was through a careful study of radioactive decays that physicists hypothesized the neutrino's existence. For example: (1) In a radioactive nucleus, a neutron at rest (zero momentum) decays, releasing a proton and an electron. (2) Because of the law of conservation of momentum, the resulting products of the decay must have a total momentum of zero, which the observed proton and electron clearly do not. (Furthermore, if there are only two decay products, they must come out back-to-back.) (3) Therefore, we need to infer the presence of another particle with appropriate momentum to balance the event. (4) We hypothesize that an antineutrino was released; experiments have confirmed that this is indeed what happens. Because neutrinos were produced in great abundance in the early universe and rarely interact with matter, there are a lot of them in the Universe. Their tiny mass but huge numbers may contribute to total mass of the universe and affect its expansion.

**\*Go to the website to find out more about how these particles are bound together and why they are so important!**

1. Explain why a protons and an electron are not antiparticles of each other.
2. Using isotope symbols show how electrons and positrons annihilate each other when in contact and are considered antiparticles.
3. Describe a proton in terms of Quarks, baryons, mesons, and/or leptons.
4. Describe a neutron in terms of Quarks, baryons, mesons, and/or leptons.
5. Describe an electron in terms of Quarks, baryons, mesons, and/or leptons.

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