Questions 1 through 3 refer to the following:

In the modern model of the atom, each atom is composed of three major subatomic (or fundamental) particles.

1) Name the subatomic particles contained in the nucleus of the atom.

2) State the charge associated with each type of subatomic particle contained in the nucleus of the atom.

3) What is the net charge of the nucleus?

4) John Dalton was an English scientist who proposed that atoms were hard, indivisible spheres. In the modern model, the atom has a different internal structure.
   (a) Identify one experiment that led scientists to develop the modern model of the atom.
   (b) Describe this experiment.
   (c) State one conclusion about the internal structure of the atom, based on this experiment.

5) In the early 1900s, experiments were conducted to determine the structure of the atom. One of these experiments involved bombarding gold foil with alpha particles. Most alpha particles passed directly through the foil. Some, however, were deflected at various angles. Based on this alpha particle experiment, state two conclusions that were made concerning the structure of an atom.

6) In the early 1900s, evidence was discovered that atoms were not "hard spheres." It was shown that atoms themselves had an internal structure. One experiment involved gold metal foil.

(a) In the diagram above, complete the simple model for an atom of gold-197 by placing the correct numbers in the two blanks.

(b) In the gold-foil experiment, alpha particles were directed toward the foil. Most of the alpha particles passed directly through the foil with no effect. This result did not agree with the "hard spheres model" for the atom. What conclusion about the internal structure of the atom did this evidence show?

(c) In the same experiment, some of the alpha particles returned toward the source. What does this evidence indicate about the charge of the atom's nucleus?
Questions 7 through 9 refer to the following:

One model of the atom states that atoms are tiny particles composed of a uniform mixture of positive and negative charges. Scientists conducted an experiment where alpha particles were aimed at a thin layer of gold atoms. Most of the alpha particles passed directly through the gold atoms. A few alpha particles were deflected from their straight-line paths. An illustration of the experiment is shown below.

7) According to the diagram, most of the alpha particles passed directly through the gold atoms undisturbed. What does this evidence suggest about the structure of the gold atoms?

8) A few of the alpha particles shown in the diagram were deflected. What does this evidence suggest about the structure of the gold atoms?

9) How should the original model be revised based on the results of the experiment shown in the diagram?

Questions 10 through 12 refer to the following:

A glass tube is filled with hydrogen gas at low pressure. An electric current is passed through the gas, causing it to emit light. This light is passed through a prism to separate the light into the bright, colored lines of hydrogen’s visible spectrum. Each colored line corresponds to a particular wavelength of light. One of hydrogen’s spectral lines is red light with a wavelength of 656 nanometers. Tubes filled with other gases produce different bright-line spectra that are characteristic of each kind of gas. These spectra have been observed and recorded.

10) Explain, in terms of electron energy states and energy changes, how hydrogen’s bright-line spectrum is produced.

11) Explain how the elements present on the surface of a star can be identified using bright-line spectra.

12) A student measured the wavelength of hydrogen’s visible red spectral line to be 647 nanometers. Based on the information in the reading passage, show a correct numerical setup for calculating the student’s percent error.
Questions 13 and 14 refer to the following:

Many advertising signs depend on the production of light emissions from gas-filled glass tubes that are subjected to a high-voltage source. When light emissions are passed through a spectroscope, bright-line spectra are produced.

![Diagram of gas mixtures]

13) Identify the two gases in the unknown mixture in the given diagram.

14) Explain the production of an emission spectrum in terms of the energy states of an electron.

Questions 15 and 16 refer to the following:

The diagram below shows bright-line spectra of selected elements.

![Diagram of bright-line spectra]

15) Identify the two elements in the given unknown spectrum.

16) Explain how a bright-line spectrum is produced, in terms of excited state, energy transitions, and ground state.

17) What is the total number of neutrons in an atom of aluminum-27?

18) Naturally occurring elemental carbon is a mixture of isotopes. The percent composition of the two most abundant isotopes is listed below.

- d 98.93% of the carbon atoms have a mass of 12.00 atomic mass units.
- d 1.07% of the carbon atoms have a mass of 13.00 atomic mass units.

Write a correct numerical setup for calculating the average atomic mass of carbon.
19) The table below gives information about two isotopes of element X.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mass</th>
<th>Relative Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-10</td>
<td>10.01</td>
<td>19.91%</td>
</tr>
<tr>
<td>X-11</td>
<td>11.01</td>
<td>80.09%</td>
</tr>
</tbody>
</table>

Calculate the average atomic mass of element X. [Show a correct numerical setup. Express your answer to the correct number of significant figures.]

20) The data table below shows three isotopes of neon.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Atomic Mass (atomic mass units)</th>
<th>Percent Natural Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>^20Ne</td>
<td>19.99</td>
<td>90.9%</td>
</tr>
<tr>
<td>^21Ne</td>
<td>20.99</td>
<td>0.3%</td>
</tr>
<tr>
<td>^22Ne</td>
<td>21.99</td>
<td>8.8%</td>
</tr>
</tbody>
</table>

Based on natural abundances shown in the table, the average atomic mass of neon is closest to which whole number?

21) Describe, in terms of subatomic particles found in the nucleus, one difference between the nuclei of carbon-12 atoms and the nuclei of carbon-13 atoms. [The response must include both isotopes.]

22) Two isotopes of potassium are K-37 and K-42.

(a) What is the total number of neutrons in the nucleus of a K-37 atom?

(b) How many valence electrons are in an atom of K-42 in the ground state?

(c) Explain, in terms of subatomic particles, why K-37 and K-42 are isotopes of potassium.

23) Explain, in terms of atomic structure, why germanium is chemically similar to silicon.
Questions 24 and 25 refer to the following:

The diagram below represents an atom of magnesium-26 in the ground state.

24) According to the diagram, what is the total number of valence electrons in an atom of Mg-26 in the ground state?

25) On the diagram below, write an appropriate number of electrons in each shell to represent a Mg-26 atom in an excited state. *Your answer may include additional shells.*

Questions 26 and 27 refer to the following:

An atom has an atomic number of 9, a mass number of 19, and an electron configuration of 2-6-1.

26) What is the total number of neutrons in the atom described?

27) Explain why the number of electrons in the second and third shells shows that the atom described is in an excited state.

Questions 28 and 29 refer to the following:

<table>
<thead>
<tr>
<th>Element</th>
<th>Electron Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>2-8-8-2</td>
</tr>
<tr>
<td>Y</td>
<td>2-8-7-3</td>
</tr>
<tr>
<td>Z</td>
<td>2-8-8</td>
</tr>
</tbody>
</table>

28) What is the total number of valence electrons in an atom of electron configuration X?
29) What electron configuration represents the excited state of a calcium atom?

30) What is the total number of electrons found in an atom of sulfur?
   A) 6       B) 16       C) 32       D) 8

31) Compared to a calcium atom, the calcium ion Ca²⁺ has
   A) more protons       B) more electrons       C) fewer electrons       D) fewer protons

32) An oxide ion (O²⁻) formed from an oxygen-18 atom contains exactly
   A) 8 protons, 10 neutrons, 10 electrons       B) 10 protons, 8 neutrons, 8 electrons
   C) 8 protons, 8 neutrons, 10 electrons       D) 8 protons, 10 neutrons, 8 electrons

33) What is the total number of electrons in a Cu⁺ ion?
   A) 30       B) 36       C) 28       D) 29

34) Which symbol represents a particle with a total of 10 electrons?
   A) Al       B) N³⁺       C) N       D) Al³⁺

35) What is the total number of electrons in an S²⁻ ion?
   A) 10       B) 16       C) 18       D) 14