1. Which statement regarding the gold foil experiment is **false**?

(a) It was performed by Rutherford and his research group early in the 20th century.
(b) Most of the alpha particles passed through the foil undeflected.
(c) The alpha particles were repelled by electrons
(d) It suggested the nuclear model of the atom.
(e) It suggested that atoms are mostly empty space.

2. Ernest Rutherford's model of the atom did not specifically include the ____.

(a) neutron
(b) nucleus
(c) proton
(d) electron
(e) electron or the proton

3. The gold foil experiment suggested ____.

(a) that electrons have negative charges
(b) that protons have charges equal in magnitude but opposite in sign to those of electrons
(c) that atoms have a tiny, positively charged, massive center
(d) the ratio of the mass of an electron to the charge of an electron
(e) the existence of canal rays

4. Which statement is false?

(a) Ordinary chemical reactions do not involve changes in nuclei.
(b) Atomic nuclei are very dense.
(c) Nuclei are positively charged.
(d) Electrons contribute only a little to the mass of an atom.
(e) The nucleus occupies nearly all the volume of an atom.
5. In interpreting the results of his "oil drop" experiment in 1909, ____ was able to determine ____.

(a) Robert Millikan; the charge on a proton
(b) James Chadwick; that neutrons are also present in the nucleus
(c) James Chadwick; that the masses of protons and electrons are nearly identical
(d) Robert Millikan; the charge on an electron
(e) Ernest Rutherford; the extremely dense nature of the nuclei of atoms

6. Which is a possible explanation for why the neutron was the last of the three fundamental subatomic particles to be discovered?

(a) The atoms of very few elements contain neutrons in their nuclei.
(b) Its existence was not suspected until Rutherford's gold foil experiment.
(c) It was difficult to detect because it has no charge.
(d) Because its mass is similar to a proton's mass, both are affected similarly by an electric field.
(e) It is difficult to detect because it is located outside the nucleus with the more numerous, negatively charged electrons.

7. Complete the chart for neutral atoms.

<table>
<thead>
<tr>
<th>name of atom</th>
<th>atomic number</th>
<th>mass number</th>
<th>nuclide symbol</th>
<th>number of protons</th>
<th>number of electrons</th>
<th>number of neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>neon</td>
<td>10</td>
<td>21</td>
<td>$^{21}_{10}$Ne</td>
<td>10</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>chlorine</td>
<td>17</td>
<td>35</td>
<td>$^{35}_{17}$Cl</td>
<td>17</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>nickel</td>
<td>28</td>
<td>58</td>
<td>$^{58}_{28}$Ni</td>
<td>28</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>selenium</td>
<td>34</td>
<td>74</td>
<td>$^{74}_{34}$Se</td>
<td>34</td>
<td>34</td>
<td>40</td>
</tr>
<tr>
<td>bromine</td>
<td>35</td>
<td>81</td>
<td>$^{81}_{35}$Br</td>
<td>35</td>
<td>35</td>
<td>46</td>
</tr>
<tr>
<td>rhodium</td>
<td>45</td>
<td>104</td>
<td>$^{104}_{45}$Rh</td>
<td>45</td>
<td>45</td>
<td>59</td>
</tr>
<tr>
<td>argon</td>
<td>18</td>
<td>40</td>
<td>$^{40}_{18}$Ar</td>
<td>18</td>
<td>18</td>
<td>22</td>
</tr>
</tbody>
</table>
8. Complete the chart for the ions shown.

<table>
<thead>
<tr>
<th>formula of</th>
<th>A</th>
<th>Z</th>
<th>nuclide symbol</th>
<th>#p(^+)</th>
<th>#e(^-)</th>
<th>#n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag(^+)</td>
<td>108</td>
<td>47</td>
<td>¹⁰⁸(^{47})Ag(^+)</td>
<td>47</td>
<td>46</td>
<td>61</td>
</tr>
<tr>
<td>Fe(^{2+})</td>
<td>56</td>
<td>26</td>
<td>⁵⁶(^{26})Fe(^{2+})</td>
<td>26</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>S(^{2-})</td>
<td>32</td>
<td>16</td>
<td>³²(^{16})S(^{2-})</td>
<td>16</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Br(^-)</td>
<td>79</td>
<td>35</td>
<td>⁷⁹(^{35})Br(^-)</td>
<td>35</td>
<td>36</td>
<td>44</td>
</tr>
</tbody>
</table>

9. Bromine is composed of \(^{79}\)Br, 78.9183 amu and \(^{81}\)Br, 80.9163 amu. The percent composition of a sample is 50.69% \(^{79}\)Br and 49.31% \(^{81}\)Br. Based on this sample, calculate the atomic mass of Br.

\[
\text{atomic mass} = (0.5069)(78.9183 \text{ amu}) + (0.4931)(80.9163 \text{ amu})
\]

\[
\text{atomic mass} = 40.00 \text{ amu} + 39.90 \text{ amu} = 79.90 \text{ amu}
\]

10. Naturally occurring iron consists of 4 isotopes with the natural abundances indicated. From the data given, calculate the average atomic mass of iron.

<table>
<thead>
<tr>
<th>isotope</th>
<th>mass (amu)</th>
<th>% natural abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{54})Fe</td>
<td>53.9396</td>
<td>5.82</td>
</tr>
<tr>
<td>(^{56})Fe</td>
<td>55.9349</td>
<td>91.66</td>
</tr>
<tr>
<td>(^{57})Fe</td>
<td>56.9354</td>
<td>2.19</td>
</tr>
<tr>
<td>(^{58})Fe</td>
<td>57.9333</td>
<td>0.33</td>
</tr>
</tbody>
</table>

\[
\text{atomic mass} = (0.0582)(53.9396 \text{ amu}) + (0.9166)(55.9349 \text{ amu}) + (0.0219)(56.9354 \text{ amu}) + (0.0033)(57.9333 \text{ amu})
\]

\[
\text{atomic mass} = 3.14 \text{ amu} + 51.27 \text{ amu} + 1.25 \text{ amu} + 0.19 \text{ amu} = 55.85 \text{ amu}
\]

11. The atomic mass of lithium is 6.941 amu. The two naturally occurring isotopes are \(^{6}\)Li, 6.01512 amu, and \(^{7}\)Li, 7.01600 amu. Calculate the % of \(^{6}\)Li in naturally occurring lithium.

\[
x = \text{fraction of } 1 \text{ that is } ^{7}\text{Li}; (1-x) = \text{fraction of } 1 \text{ that is } ^{6}\text{Li}
\]

\[
6.941 \text{ amu} = (7.01600 \text{ amu})x + (6.01512 \text{ amu})(1-x)
\]

\[
6.941 = 7.01600x + 6.01512(1-x)
\]

\[
6.941 = 7.01600x + 6.01512 - 6.01512x
\]

\[
6.941 - 6.01512 = 7.01600x - 6.01512x
\]

\[
0.926 = 1.00088x
\]
$x = \frac{0.926}{1.00088} = 0.925; \ (1-x) = 0.075$

92.5% $^7$Li and 7.5% $^6$Li

12. The atomic mass of rubidium is 85.4678 amu. The two naturally occurring isotopes are $^{85}$Rb, 84.9118 amu, and $^{87}$Rb, 86.9092 amu. Calculate the percent $^{85}$Rb in naturally occurring rubidium.

\[
x = \text{fraction of 1 that is } ^{87}\text{Rb and } (1-x) = \text{the fraction of 1 that is } ^{85}\text{Rb}
\]

\[
85.4678 \text{ amu} = (86.9092 \text{ amu})x + (84.9118 \text{ amu})(1-x)
\]

\[
85.4678 = 86.9092x + 84.9118 - 84.9118x
\]

\[
85.4678 - 84.9118 = 86.9092x - 84.9118x
\]

\[
0.5560 = 1.9974x
\]

\[
x = 0.5560 = 0.2784; \ (1-x) = 0.7216
\]

27.84% $^{87}$Rb and 72.16% $^{85}$Rb

13. Calculate the wavelength, in nanometers (nm) of radiation that has a frequency of $5.60 \times 10^{15}$ s$^{-1}$.

\[
\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{5.60 \times 10^{15} \text{ 1/s}} = 5.36 \times 10^{-7} \text{ m}; \ 5.36 \times 10^{-7} \text{ m} \mid 1 \times 10^9 \text{ nm} \mid = 53.6 \text{ nm}
\]

14. Calculate the frequency of light that has the following wavelengths:

(a) 8973 Å

\[
\lambda = \frac{8973 \text{ Å}}{1 \times 10^{10} \text{ Å}} = 8.973 \times 10^{-7} \text{ m}; \ \nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{8.973 \times 10^{-7} \text{ m}} = 3.34 \times 10^{14} \text{ s}^{-1}
\]

(b) 492 nm

\[
\lambda = \frac{492 \text{ nm}}{1 \times 10^9 \text{ nm}} = 4.92 \times 10^{-7} \text{ m}; \ \nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{4.92 \times 10^{-7} \text{ m}} = 6.10 \times 10^{14} \text{ s}^{-1}
\]

(c) 492 cm.

\[
\lambda = \frac{492 \text{ cm}}{100 \text{ cm}} = 4.92 \text{ m}; \ \nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{4.92 \text{ m}} = 6.10 \times 10^7 \text{ s}^{-1}
\]
15. Excited lithium ions emit radiation at a wavelength of 671 nm in the visible range of the spectrum. Calculate the energy of a photon of this light.

\[
\frac{671 \text{ nm}}{1 \text{ m}} = 6.71 \times 10^{-7} \text{ m}
\]
\[
\frac{1 \times 10^9 \text{ nm}}{}
\]
\[
E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{6.71 \times 10^{-7} \text{ m}} = 2.96 \times 10^{-19} \text{ J}
\]

16. Calculate the wavelength, in Å, of X-rays that has an energy of 6.6 x 10^{-16} J.

\[
E = \frac{hc}{\lambda} \quad \rightarrow \quad \lambda = \frac{hc}{E}
\]
\[
\lambda = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{6.6 \times 10^{-16} \text{ J}}
\]
\[
\lambda = 3.0 \times 10^{-10} \text{ m} \quad \frac{1 \times 10^{10} \text{ Å}}{1 \text{ m}} = 3.0 \text{ Å}
\]

17. A typical broadcast frequency for a radio station might be 89.5 MHz.

(a) What is the wavelength, in meters, of this frequency?

\[
\frac{89.5 \text{ MHz}}{1 \times 10^6 \text{ Hz}} = 8.95 \times 10^7 \text{ s}^{-1}; \quad \lambda = \frac{c}{v} = 3.00 \times 10^8 \text{ m/s} = 3.35 \text{ m}
\]
\[
\frac{1 \text{ MHz}}{8.95 \times 10^7 \text{ 1/s}}
\]

(b) What is the energy, in Joules, of one photon of this electromagnetic radiation?

\[
E = hv = (6.626 \times 10^{-34} \text{ J} \cdot \text{s})(8.95 \times 10^7 \text{ s}^{-1}) = 5.93 \times 10^{-26} \text{ J}
\]

18. Which of the responses contains all the statements that are consistent with the Bohr theory of the atom (and no others)?

I. An electron can remain in a particular orbital as long as it continually absorbs radiation of a definite frequency.
II. The lowest energy orbitals are those closest to the nucleus.
III. An electron can jump from the K shell to the M shell by emitting radiation of a definite frequency.
19. Which one of the following statements is not consistent with the Bohr theory?

(a) An electron moves in a circular orbit around the nucleus.
(b) The energy of an electron is quantized.
(c) An electron may move to a lower energy orbital by emitting radiation of a frequency proportional to the energy difference between the two orbitals.
(d) An electron may move to a higher energy orbital by absorbing radiation of a frequency proportional to the energy difference between the two orbitals.
(e) An atom has a number of discrete energy levels (orbits) in which an electron can exist as long as it continually emits radiation of a definite energy.

20. The Heisenberg Uncertainty Principle states that ___.

(a) no two electrons in the same atom can have the same set of four quantum numbers
(b) two atoms of the same element have the same number of protons
(c) it is impossible to determine accurately both the position and energy of an electron simultaneously
(d) electrons in atoms in their ground states enter energetically equivalent sets of orbitals singly before they pair up in any orbital of the set
(e) charged atoms (ions) must generate a magnetic field when they are in motion

21. Which response includes all the following statements that are true, and no others?

I. When an electron falls to a lower energy level in an atom, it can emit electromagnetic radiation in order to release the excess energy.
II. The energy of electromagnetic radiation is directly proportional to its frequency.
III. The product of wavelength and the speed of light is frequency.
IV. Atoms can exist only in certain energy states.

(a) I
(b) I and III
(c) II
(d) II and III
(e) I, II, and IV
22. A(An) ___ is a region of space in which there is a high probability of finding an electron in an atom.

(a) shell
(b) atomic orbital
(c) core
(d) major energy level
(e) nucleus

23. All orbitals of a given degenerate set must be singly occupied before pairing begins in that set is a statement of ___.

(a) the Aufbau Principle
(b) Dalton’s Theory
(c) The Heisenberg Uncertainty Principle
(d) The Pauli Exclusion Principle
(e) Hund’s Rule

24. The general shape of the region in space occupied by electrons is described by which quantum number?

(a) n
(b) ℓ
(c) \( m_\ell \)
(d) \( m_s \)
(e) \( \nu \)

25. Write the complete ground-state electron configuration for the following elements.

(a) N: 1s\(^2\)2s\(^2\)2p\(^3\)

(b) Cl: 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^5\)

(c) Ca: 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)

(d) Mn: 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)3d\(^5\)

(e) Ge: 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)3d\(^{10}\)4p\(^2\)
26. Write the shorthand (with noble gas core) ground-state electron configuration for the following elements.

(a) Na: [Ne]3s¹
(b) S: [Ne]3s²3p⁴
(c) Ni: [Ar]4s²3d⁸
(d) Sb: [Kr]5s²4d¹⁰5p³
(e) Bi: [Xe]6s²4f¹⁴5d¹⁰6p³

27. Draw the ground-state electron configuration using the orbital notation (\(\uparrow\downarrow\)) for the following elements.

(a) O: \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) or [He] \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\)

(b) Fe: \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) or [Ar] \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\)

(c) Cl: \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) or [Ne] \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\)

(d) Rb: [Kr] \(\uparrow\) ⁵s

(e) Si: \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\) or [Ne] \(\uparrow\downarrow\) \(\uparrow\downarrow\) \(\uparrow\downarrow\)