Chapter 10 Answer Key

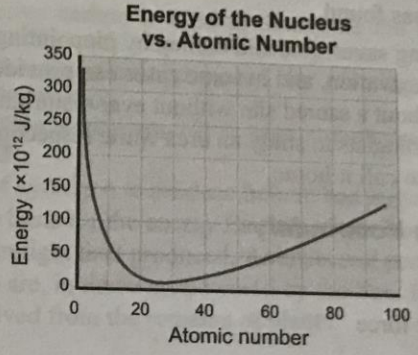
10.1 Section Review

1. The three subatomic particles are the proton, electron, and neutron. The proton is located in the nucleus and has a positive charge. The electron is found in energy levels in space around the nucleus and has a negative charge. The neutron is found in the nucleus and is an uncharged particle.
2. (a) Electrons are bound to the nucleus by electromagnetic force, first measured by Charles-Augustin de Coulomb. (b) The nucleus is held together by the strong nuclear force, predicted by Hideki Yukawa.
3. They are different elements because they do not have the same number of protons.

10.2 Section Review

1. A rainbow shows all of the separate colors of light. If you look through a prism at the light given off by a pure element, you see that the light does not contain all colors. You see a characteristic pattern of a few specific colors called a spectrum which is different for different elements.
2. The energy in atoms changes in little all-or-nothing jumps called quanta. When an electron moves from a higher energy level to a lower energy level, the atom gives up the energy difference between the two levels. The energy comes out as light of a specific color.
3. Only one electron can be in the same quantum state in the same atom at the same time.
4. *Answers will vary.* When rolling a die, the probability of getting any specific side is 1 in 6.

10.3 Section Review

1. 

   A fusion nuclear reaction releases energy when the final nucleus has lower energy than the initial nuclei, or if the final nucleus is lower on the graph than the combining nuclei. A fission nuclear reaction releases energy when the final nuclei have an average lower energy than the initial nucleus, or are lower on the graph.
2. ${}^{238}_{92}\mathrm{U} \rightarrow \alpha$ decay 4.5 billion years $\rightarrow {}^{234}_{90}\mathrm{Th}$
3. 916 years. After 458 years, half of the sample will decay. Half of the remaining americium will decay over the next 458 years, leaving one-fourth of the original sample.
4. Answers will vary. Advantages: nuclear power plants emit low levels of carbon dioxide and generate large amounts of electrical energy. Disadvantages: nuclear power plants create highly radioactive waste which is costly to store and harmful to humans.

Connection Answers

1. Indirect evidence is a type of evidence that involves finding "traces" of something's existence. For example, indirect evidence of the return of mountain lions to an area would include finding footprints or bits of the animal's fur. An example of direct evidence would be a video recording that clearly shows the animal in an identifiable setting.

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15. Because electrons are so tiny, it is impossible to find their exact position without changing them in some way which changes their position.
16. wave function

Section 10.3

17. Both chemical and nuclear reactions involve rearranging particles. Nuclear reactions change the nucleus of atoms and can, therefore, change one element into another. Chemical reactions involve the electrons but do not change the type of atoms and only rearrange atoms into different compounds. Nuclear reactions involve much more energy than chemical reactions.
18. Both reactions involve changes to the nucleus of the atoms involved. In a fusion reaction two nuclei combine or fuse together to form a single nucleus. In a fission reaction a single nucleus is broken down into smaller nuclei. Energy is released in both reactions. Fusion is the reaction responsible for the energy reaching Earth from the Sun.
19. No.
20. Because nuclear reactions involve the strong nuclear force which is a much stronger force than the electromagnetic force involved in chemical reactions.
21. Table filled in:

Decay	Proton #change	Neutron #change	Ejected particle
Alpha	decrease by 2	decrease by 2	helium-4 nucleus
Beta	increase by 1	decrease by 1	electron
Gamma	same	same	gamma ray

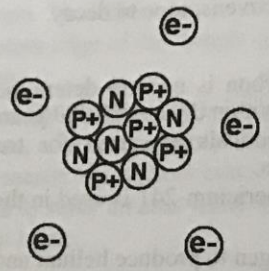
22. The periodic table is a compilation of all known chemical elements. It organizes the elements according to their chemical properties.
23. The half-life of an element is the amount of time required for half of the mass of a radioactive isotope to decay.
24. Answers are:
    a. Radioactive carbon is used to determine the age of organisms that have died within the last 57,000 years.
    b. Radiopharmaceuticals are used for treating certain illnesses including cancer.
    c. Radioactive americium-241 is used in the manufacture of smoke detectors.
25. The fusion of hydrogen to produce helium and large amounts of energy is the basis for the energy Earth receives from the Sun. Plants rely on the sunlight thus produced. Animals and people eat plant products and are, in this way, powered by the Sun. In addition, fossil fuels are derived from the remains of plants.

Solving Problems

Section 10.1

1. atomic number = 7; mass number = 15; element is nitrogen
2. 30-14 = 16 neutrons
3. Carbon-12 has 6 protons and 6 neutrons; carbon 14 has 6 protons and 8 neutrons.
4. atomic number of oxygen = 8 = number of protons
5. Answers are:
    a. 44
    b. b. 20
    c. c. calcium
6. 13

7.



boron

Section 10.2

8. Electron A emits the green photon, the higher energy photon, because it undergoes a greater change in energy levels.
9. 1/6 (or 17%); 17 times

Section 10.3

10. b, f, c, e, a, d
11. Answers are:
    a. fusion
    b. fission
    c. fusion
12. It would take 3 half lives to reduce 16 grams of radon to 2 grams of radon.
    3 half-lives × 3.8 days/half-life = 11.4 days

Test Practice

Section 10.1

1. b
2. a
3. c

Section 10.2

4. a

Section 10.3

5. c
6. d
7. c
8. a
9. c
10. a

Applying Your Knowledge

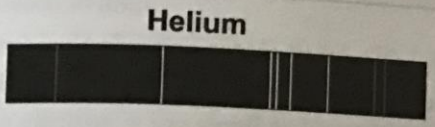
Section 10.1

1. You may wish to ask students to do additional research on the internet or in the library. Student answers should reflect that the Thomson model of the atom reflected his discovery of the electron, which carries a negative charge. The Rutherford model, based on his gold foil experiment, introduced the nucleus to the atomic model. The Bohr model introduced the idea that electrons have fixed amounts of energy. The Schrodinger model reflected discoveries of the wavelength nature of electrons.
2. The most challenging part of this project will be for your students to figure out how to show the electrons orbit in different energy levels. This aspect of the project makes it suitable as a group project. Students enjoy working together to solve problems such as how to accurately model an atom. Challenge them to try to be as accurate as possible. For an extra challenge, have them try to model an atom with a high atomic model.)

Section 10.2

3. A web site showing several alternate forms of the periodic table is: http://www.wou.edu/las/physci/ch412/alttable.htm. Alternate forms of the periodic table have been developed because the elements form a complex pattern and there are a number of different ways of organizing and looking at them, depending upon what information about elements you need.

4.



Wavelength (nm)	Color	Energy
389	violet	highest
402	violet	
447	blue	
471	blue green	
502	green	
588	yellow	
668	red	
707	deep red	lowest

The lowest wavelength corresponds to the highest energy. Violet lines have the highest energy and red have the lowest. The red lines are to the left in the graphic and the blue/violet are to the right.

Section 10.3

5. Answers include:

a. Challenges include the extremely high temperatures needed, in excess of 100 million℃, and the high pressure required in the reaction. In addition, it is very difficult to remove enough impurities from the plasma and the process.

b. The fuel for the reaction is abundant – hydrogen is very commonly found on Earth. Nuclear fusion has no significant radioactive by-products. Another advantage is that the process is self-regulating and does not "runaway."

c. Magnetic containment fusion use magnetic fields to contain the plasma during the reaction. Any material used to confine the process would not withstand the high temperatures required, so by containing the plasma with magnetic fields, the reactor is protected from high temperatures. One experimental reactor using magnetic containment is the tokamak approach used in the Tokamak Fusion Test Reactor.)

Skill and Practice Sheet Answers

10A Structure of the Atom

1. Answers are:

lithium	3	7
carbon	6	12
hydrogen	1	1
hydrogen (a radioactive isotope, 3H, called tritium)	1	3
beryllium	4	9

2. Answers are:
   a. hydrogen-2: 1 proton, 1 neutron
   b. scandium-45: 21 protons, 24 neutrons
   c. aluminum-27: 13 protons, 14 neutrons
   d. uranium-235: 92 protons, 143 neutrons
   e. carbon-12: 6 protons, 6 neutrons
3. Most of an atom's mass is concentrated in the nucleus. The number of electrons and protons is the same but electrons are so light they contribute very little mass. The mass of the proton is 1,835 times the mass of the electron. Neutrons have a bit more mass than protons, but the two are so close in size that we usually assume their masses are the same.
4. Yes, it has a proton (+1) and no electrons to balance charge. Therefore, the overall charge of this atom (now called an ion) is +1.
5. This sodium atom has 10 electrons, 11 protons, and 12 neutrons.

10B Atoms and Isotopes

Part 1 Answers:

1. protium has 0 neutrons; deuterium has 1 neutron; tritium has 2 neutrons
2. Answers are:
   a. 3
   b. Lithium
   c. 7
   d. $^{7}_{3}Li$

Part 2 Answers:

1. Bromine-80
2. Potassium-39 has 20 neutrons.
3. Lithium-7
4. Neon-20 has 10 neutrons.

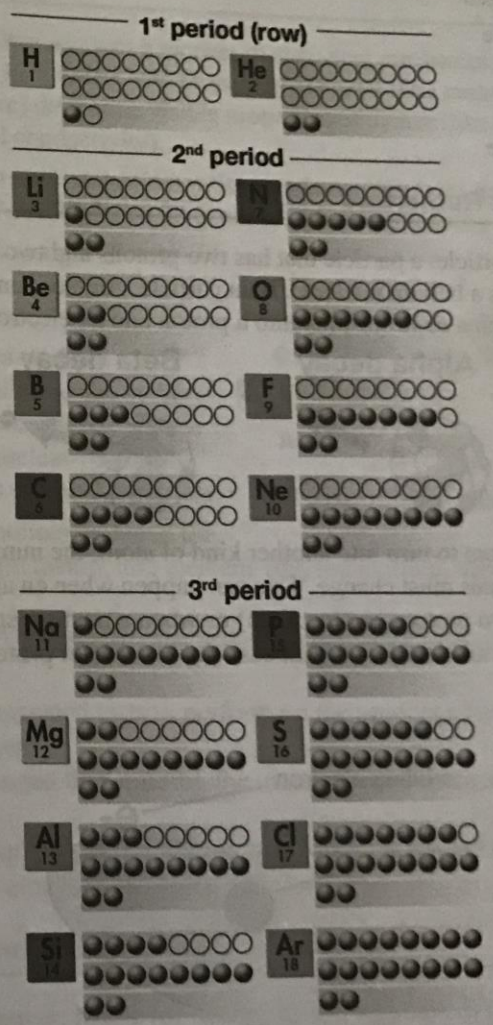
10C The Periodic Table

Note: Students use library or Internet resources to complete this skill sheet.

1. Fluorine
2. Argon
3. Manganese
4. Phosphorous
5. Technetium
6. The atomic number tells the number of protons in an atom of the element.
7. Iron, 55.8 amu
8. Cesium, 132.9 amu
9. Silicon, 28.1 amu
10. Sodium, 23.0 amu
11. Bismuth, 209.0 amu

12. The atomic mass tells the average mass of all known isotopes of an element, expressed in amu.
13. The atomic mass isn't always a whole number because it is an average mass of all known isotopes.
14. The mass of an electron is too small to be significant.
15. Alkali metals
16. Any two of the following:
soft, silvery, highly reactive, combines in 2:1 ratio with oxygen
17. Any three of the following:
F, Cl, Br, I, At
18. They are toxic gases or liquids in pure form, highly reactive, and form salts with alkali metals.
19. In the far right column
20. They rarely form chemical bonds with other atoms.

21. See figure, below

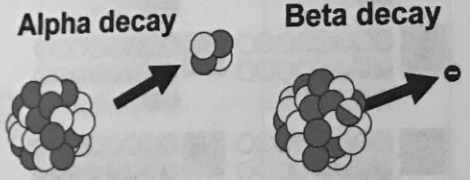


22. as above
23. as above
24. as above
25. as above

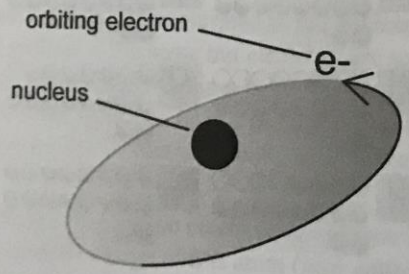
26. Hydrogen
27. Fluorine
28. Carbon
29. Sodium
30. Chlorine

10D Ernest Rutherford

1. Alpha particle: a particle that has two protons and two neutrons (also known as a helium nucleus). Beta particle: An electron emitted by an atom when a neutron splits into a proton and an electron.



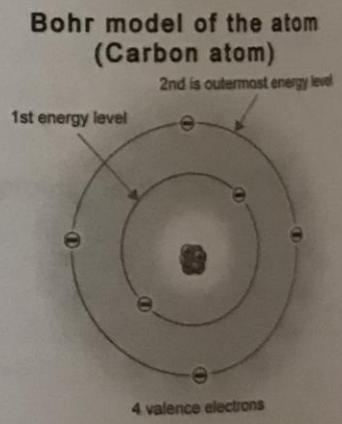
2. For one atom to turn into another kind of atom, the number of protons in the nucleus must change. This can happen when an alpha particle is ejected (two protons are lost then) or when a neutron splits into a proton and an electron (in that case the number of protons increases by one).
3. Diagram:



4. Rutherford's planetary model suggested that an atom consists of a tiny nucleus surrounded by a lot of empty space in which electrons orbit in fixed paths. Subsequent research has shown that electrons don't exist in fixed orbitals. The Heisenberg uncertainty principle tells us that it is impossible to know both an electron's position and its momentum at the same time. Scientists now discuss the probability that an electron will exist in a certain position. Computer models predict where an electron is most likely to exist, and three-dimensional shapes can be drawn to show the most likely positions. The sum of these shapes produces the charge-cloud model of the electron.
5. In the game of marbles, players "shoot" one marble at a group of marbles and then watch the deflection as collisions occur. This is a lot like what Rutherford was doing on a much, much smaller scale. Rutherford's comment is reflective of his typical self-deprecating humor. While "playing with marbles," he discovered the proton.
6. Answers will vary. Students may wish to write about one of the following discoveries: Rutherford first described two different kinds of particles emitted from radioactive atoms, calling them alpha and beta particles. He also proved that radioactive decay is possible. He developed the planetary model of the atom, and was the first to split an atom.

10E Niels Bohr

1. Both Rutherford and Bohr described atoms as having a tiny dense core (the nucleus) surrounded by electrons in orbit. Bohr described the nature of the electrons' orbits in much greater detail.
2. Niels Bohr described electrons as existing in specific orbital pathways, and explained how atoms emit light.
3. In Bohr's model of the atom, the electrons are in different energy levels. Bohr's model of the atom is shown at right:



4. An electron absorbs energy as it jumps from an inner orbit to an outer one. When the electron falls back to the inner orbit, it releases the absorbed energy in the form of visible light.

5. Answers will vary. You may wish to ask students to research world events from the end of World War II to Bohr's death in 1962. Students should look for events that may have raised concerns in Bohr's mind about the potential use/misuse of nuclear weapons. They might also choose to research Bohr's own comments on the subject.

10F Radioactivity

1. In the answers below, "a" is alpha decay and "b" is beta decay.

a. Answers are:

$^{238}_{92}U$ a→ $^{234}_{90}Th$ b→ $^{234}_{91}Pa$ b→ $^{234}_{92}U$ a→ $^{230}_{90}Th$ a→

$^{226}_{88}Ra$ a→ $^{222}_{86}Rn$ a→ $^{218}_{84}Po$ a→ $^{214}_{82}Pb$ b→ $^{214}_{83}Bi$ b→

$^{214}_{84}Po$ a→ $^{210}_{82}Pb$ b→ $^{210}_{83}Bi$ b→ $^{210}_{84}Po$ a→ $^{206}_{82}Pb$

b. Answers are:

$^{240}_{94}Pu$ b→ $^{240}_{95}Am$ a→ $^{236}_{93}Np$ a→ $^{232}_{91}Pa$ b→ $^{232}_{92}U$ a→

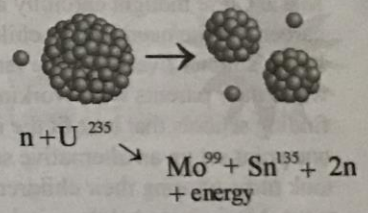
$^{228}_{90}Bi$ a→ $^{224}_{88}Ra$ b→ $^{224}_{89}Ac$ a→ $^{220}_{87}Fr$ a→ $^{216}_{85}At$ a→

$^{212}_{83}Bi$ b→ $^{212}_{84}Po$ a→ $^{208}_{82}Pb$ b→ $^{208}_{83}Bi$

2. Answers are:
   a. During 11 minutes, fluorine-18 would experience 6 half-lives.
   b. 0.16 gram would be left after 11 minutes (660 seconds).
3. The amount after 28,650 years would be $0.0313m$ (or $1/32m$) where m is the mass of the sample.
4. For one-fourth of the original mass to be left, there must have been time for two half-lives. Therefore, the half-life for this radioactive isotope is 9 months.
5. Answers are:
   a. $0.8\ W/m^2$
   b. 3.6×10^{13} reactions per second

10G Lise Meitner

1. Ludwig Boltzmann was a pioneer of statistical mechanics. He used probability to describe how properties of atoms (like mass, charge, and structure) determine visible properties of matter (like viscosity and thermal conductivity).
2. They discovered protactinium. Its atomic number is 91 and atomic mass is 231.03588. It has 20 isotopes. All are radioactive.
3. The graphic at right illustrates fission (n = a neutron):



4. Some topics students may research and describe include nuclear power plants, nuclear weapons, nuclear-powered submarines or aircraft carriers.
5. Meitner's honors included the Enrico Fermi award, and element 109, meitnerium, named in her honor.
6. Students should include the following pieces of evidence in their letters:
   Meitner suggested tests to perform on the product of uranium bombardment.
   Meitner proved that splitting the uranium atom was energetically possible.
   Meitner explained how neutron bombardment caused the uranium nucleus to elongate and eventually split.

10H Marie and Pierre Curie

1. Sample answer: Marie (or Marya, as she was called) had a strong desire to learn and had completed all of the schooling available to young women in Poland. She was part of an illegal "underground university" that helped young women prepare for higher education. Perhaps her own thirst for knowledge fueled her empathy for the peasant children, who were also denied the right to an education.

2. Marie Curie proposed that uranium rays were an intrinsic part of uranium atoms, which encouraged physicists to explore the possibility that atoms might have an internal structure.
3. Marie and Pierre worked with uranium ores, separating them into individual chemicals. They discovered two substances that increased the conductivity of the air. They named the new substances polonium and radium.
4. Answers include nuclear physics, nuclear medicine, and radioactive dating.
5. Marie Curie thought carefully about how to balance her scientific career and the needs of her children. When the children were young, Pierre's father lived with the family and took care of the children while their parents were working. Marie spent a great deal of time finding schools that best fit the individual needs of her children and at one point set up an alternative school where she and several friends took turns tutoring their children. When her daughters were in their teens, Marie included them in her professional activities when possible. Irene, for example, helped her mother set up mobile x-ray units for wounded soldiers during the war.

10| Rosalyn Sussman Yalow

1. There are some striking similarities in the lives of Rosalyn Yalow and Marie Curie. As young women, both were outstanding math and science students. Even though Yalow was 54 years younger than Marie Curie, both faced limited higher education opportunities because they were women. Undaunted, each earned a doctorate degree in physics. Both Yalow and Curie's research focused on radioactive materials. Curie's work was at the forefront of discovery of how radiation works, while Yalow's work was to develop a new application of radiation. Both women were particularly interested in the medical uses of radiation. Each was committed to using their scientific discoveries to promote humanitarian causes. Both women won Nobel Prizes for their work (Marie Curie won two!).
2. RIA is a technique that uses radioactive molecules to measure tiny amounts of biological substances (like hormones) or certain drugs in blood or other body fluids.
3. Using RIA, they showed that adult diabetics did not always lack insulin in their blood, and that, therefore, something must be blocking their insulin's normal action. They also studied the body's immune system response to insulin injected into the bloodstream.
4. The issue of patents in medical research remains a hotly debated issue in our society. Proponents of patents, especially for new drugs, claim that because very few new drugs make it through the extensive safety and effectiveness trials required for FDA approval, research costs are very high. Patents, they claim, are the only means of recouping these research costs. On the other side of the issue, critics say that the profit motive drives research into certain types of medicines—tending to be drugs for chronic illnesses, so that patients will take the drugs for a long time. Research into drugs (like new antibiotics) that are generally taken only for a short period of time tends to be less of a priority. You may wish to have students research the pros and cons of the patent system and write a position paper or hold a class discussion or debate on the topic.