1.3 UNDERSTANDING ATOMIC MASS

PRACTICE

(Page 29)

Understanding Concepts

1.

Subatomic particle	Relative atomic mass (u)	Charge	Location
Electron	5.5×10^{-4}	1-	surrounding the atom
Proton	~1	1+	nucleus of the atom
Neutron	~1	0	nucleus of the atom

2. The proton and the neutron are responsible for most of the mass of an atom.
3. The mass number of an atom is based upon a relative scale that uses the carbon-12 atom as a standard. On this scale the proton and the neutron both have a mass close to 1 u while the electron has a mass of 0.000 55 u.
4. $Z = 14$

   $N = 13$

   $$A = Z + N$$
   $$= 14 + 13$$
   $$A = 27$$

5. (a) $Z = 15$

   (b) $A = 31$

   $Z = 15$

   $$N = A - Z$$
   $$N = 31 - 15$$
   $$N = 16$$

(c) The element is phosphorus.

6. $A = 37$

   $Z = 17$

   $$N = A - Z$$
   $$N = 37 - 17$$
   $$N = 20$$

7. These atoms are of two elements, and so are not isotopes of each other. Each atom has a different atomic number — a different number of protons. One atom has Z = 15, or 15 protons (phosphorus), and the other atom has Z = 14, or 14 protons (silicon).
8. (a) 24 u, 25 u, and 26 u.

   (b) A = 24, 25, and 26, respectively.

   Z = 12 for all isotopes.

   $$N = A - Z$$

   For A = 24, $N = 24 - 12 = 12$ neutrons

   For A = 25, $N = 25 - 12 = 13$ neutrons

   For A = 26, $N = 26 - 12 = 14$ neutrons

   (c) A = 24, 80%; A = 25, 10%; A = 26, 10%

ACTIVITY 1.3.1 MODELLING HALF-LIFE

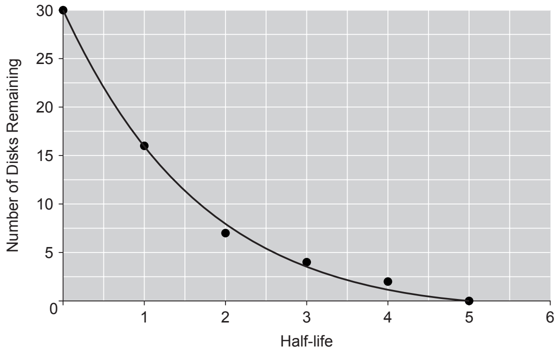
(Page 31)

(a) Table 2

Half-life	Number of disks remaining
0	30
1	16
2	7
3	4
4	2
5	0

The "heads" of the coin were used to represent the original radioactive isotope in this sample.

Analysis



(b) The graph is downward-sloping — very steep slope at first, then becoming more gradual.

(c) If the graph is used to make the prediction, the answer will often be 0 g.

Start with 30 g of radioactive material:
After 2 a (one half-life), 16 g of radioactive material would remain.
After 4 a (two half-lives), 7 g of radioactive material would remain.
After 6 a (three half-lives), 4 g of radioactive material would remain.

(d) Some graphs will reach zero in this activity, others won't. However, if the activity were continued, all graphs would reach zero - the last disk(s) will eventually flip.

(e) The removed disks represent atoms that have decayed. This model of radioactive decay is based upon the likelihood that each time the box is shaken, about half of the remaining disks will "shake" to show the original side of the disk, and the other half will "shake" to show the other side. The model is a good one in the sense that each shake does result in showing approximately half of one side of the disk and half of the other side of the disk in each half-life. Thus, the model is helpful in describing the half-life effect for radioactive material. However, the model is less than perfect because of numbers. Because the number of disks is small, it's possible to get large variations from the ideal "half per shake", and so the graph is not likely to be smooth. In any macroscopic sample of matter the number of atoms is monstrous. Because of the numbers it is not likely that there will be a wide variation from the half in any given half-life, so it is unlikely that a sample of a radioactive element will decay entirely in any reasonable time. An activity that counted atoms (if such were possible) would always produce a graph that smoothly approached, but never actually reached, the *x*-axis.

PRACTICE

(Page 32)

Understanding Concepts

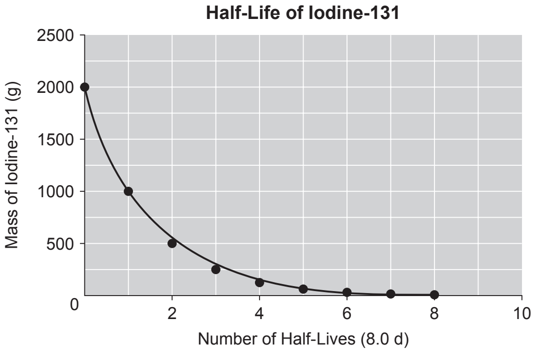
9. An isotope is a form of an element that has a certain number of neutrons. A radioisotope is an isotope of an element that emits radiation and in so doing becomes an isotope of another element.

10.

Table 3: Emission Particles

	Alpha particle	Beta particle
(a) Another name for this particle	nucleus of a helium atom	high-energy electrons
(b) The symbol for this particle	α	β
(c) How the nucleus of a radioisotope is altered by emission of this particle	loss of two protons, and two neutrons (reduction in mass number by 4)	loss of a neutron, and gain of a proton (no change in mass but atomic number is increased by 1)
(d) The penetrating ability of this type of radiation	a few centimetres in air	a few metres in air

11. Many elements have one or more isotopes that are unstable. Atoms of unstable isotopes decay, emitting radiation as their nucleus changes. Isotopes that decay in this way are known as radioisotopes and are said to be radioactive. Every radioisotope has a characteristic property called its half-life. The half-life of a radioactive substance is the time taken for half of the original number of radioactive atoms to decay. Another way of defining the term half-life is the time it takes for one-half the nuclei in a radioactive sample to decay.
12. (a) After 8.0 d (two half-lives), 1.7 g of radon-222 would remain.
    (b) After 16.0 d (four half-lives), 0.42 g of radon-222 would remain.
    (c) After 32.0 d (eight half-lives), 0.026 g of radon-222 would remain.
13. Start with 2.0 kg, or 2000 g, of iodine-131:
    After 8.0 d (one half-life), 1000 g of iodine-131 would remain.
    After 16.0 d (two half-lives), 500 g of iodine-131 would remain.
    After 24.0 d (three half-lives), 250 g of iodine-131 would remain.
    After 32.0 d (four half-lives), 125 g of iodine-131 would remain.
    After 40.0 d (five half-lives), 62.5 g of iodine-131 would remain.
    After 48.0 d (six half-lives), 31.2 g of iodine-131 would remain.
    After 56.0 d (seven half-lives), 15.6 g of iodine-131 would remain.
    After 64.0 d (eight half-lives), 7.81 g of iodine-131 would remain.



14. Radioactive decay supports the law of conservation of mass, as matter is not being created or destroyed — the matter that is emitted continues to exist in the form of protons, neutrons, and electrons.

Making Connections

15. The student is to use the Internet to research and report on a project where scientists are using or have used carbon-14 dating to find the age of artifacts. The report should cover the scientists' work and its implications.
    The number of possible projects they might discover is huge. Carbon-14 dating is standard in most archaeological excavations. For example, carbon-14 dating of artifacts from a site in South America implies that human beings were established in the Americas long before 15 000 years ago. This has generated considerable scientific discussion.

    GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

16. The student is to use the Internet to research and report on the properties and applications of a radioisotope. The student is to include at least one argument in support of its use, and one argument against.

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

17. Some circumstances in which a Geiger counter would be useful:
    - Medical facilities that use radioactive materials
    - Nuclear power facilities
    - Disposal sites for radioactive waste
18. The student is to use the Internet to research and find information related to the production, storage, and practical uses of tritium. Also, the student is to find out what precautions must be taken when working with this radioactive substance.

    In Ontario, tritium is produced at facilities connected to CANDU reactors and stored on-site.

    GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

PRACTICE

(Page 33)

Making Connections

19. The student is to use the Internet to research and report on a career in nuclear science. The report should include the following:
    - a general description of the work and how radioisotopes are involved;
    - current working conditions and a typical salary;
    - the education required to work in this field;
    - a forecast of employment trends in this field.

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

PRACTICE

(Page 35)

Understanding Concepts

20. Two advantages associated with nuclear power:
    - Nuclear plants are not associated with immediate environmental pollution such as acid rain, greenhouse gases, or the emission of toxic gases, all of which result from the burning of fossil fuels.
    - Unlike hydroelectric plants, which must be built where the water is, nuclear plants can be built close to where the power is needed.

    Two disadvantages associated with nuclear power:
    - Nuclear plants generate long-lived radioactive waste. Currently, there is no socially acceptable solution for the storage of this waste.
    - Ground water contamination from radioactive tailings at uranium ore mines is a problem.
21. CANDU reactors use the naturally occurring radioisotope of uranium:uranium-235 (U-235).
22. (a) Heavy water is water that contains deuterium instead of hydrogen (D_2O).
    (b) The nuclear fission reaction produces new neutrons that are travelling too quickly to be used for further fission reactions. Heavy water serves as a “moderator” to slow down neutrons. It is also used to cool the fuel bundles in the reactor.
23. As every technology has risks, we need to decide if the benefits of nuclear power are high enough and the risks low enough to continue using the technology. There can be many positions, generally determined by the values that an individual or a society holds on a single issue. Which solution is “best” is a matter of opinion; ideally, the solution that is implemented is the one that is most appropriate for society as a whole. Refer to text Appendix A2, “Decision Making” and “A Risk – Benefit Analysis Model.”

EXPLORE AN ISSUE DEBATE: DISPOSING OF NUCLEAR WASTE

(Page 36)

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

PRACTICE

(Page 36)

Making Connections

24. The student is to use the Internet to research and present findings on how forensic scientists use the technique of neutron bombardment to detect small or trace amounts of poisons in human tissue.

    GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

25. The student is to use the Internet to research and report on the use and handling precautions of one of the radioisotopes produced within the core of a nuclear reactor, such as cobalt-60 or iodine-131. These radioisotopes are often used for medical diagnosis and therapy, or for industrial and research work.

    GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

26. The student is to research and report on the significance of the contribution to atomic theory made by Harriet Brooks, a Canadian, and Ernest Rutherford, a New Zealander, working at McGill University in Montreal.

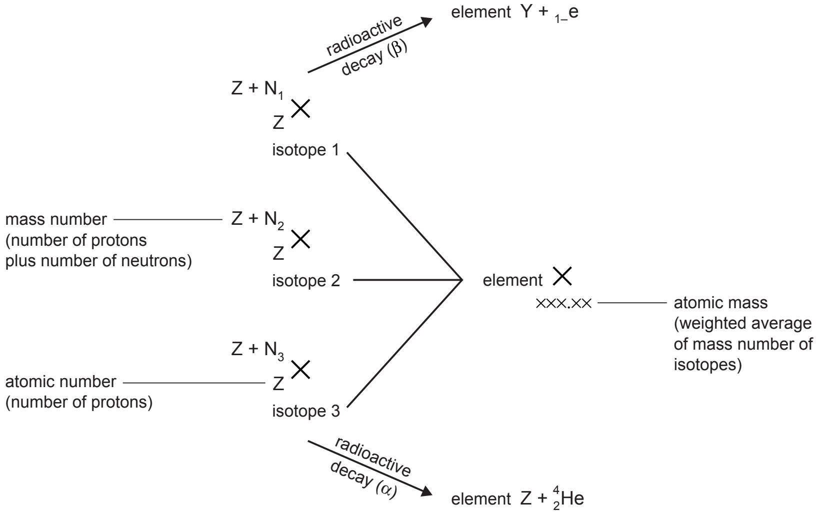
    GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

SECTIONS 1.2-1.3 QUESTIONS

(Page 37)

Understanding Concepts

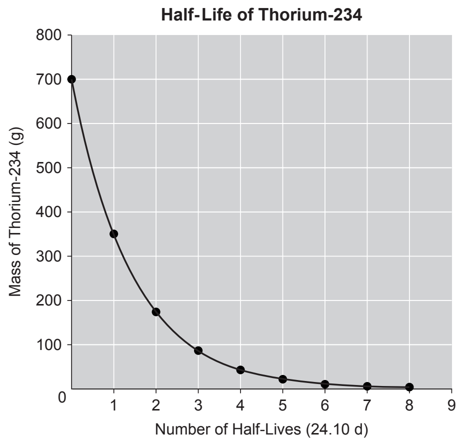
1. (a) An atom is composed of a nucleus, containing protons and neutrons, and anumber of electrons equal to the number of protons; an atom is electrically neutral.
   (b) The number of protons in the nucleus determines the identity of an element and is referred to as that element's atomic number (*Z*). The number of electrons is equal to the number of protons.
   The sum of the number of protons and neutrons present in the nucleus of an atom equals the mass number (*A*).
   (c) The element has one or more isotopes. An isotope is a form of an element in which the atoms have the same number of protons as all other forms of that element, but a different number of neutrons - isotopes have the same atomic number (*Z*), but different neutron numbers (*N*), and so different mass numbers (*A*).
2.



3. (a) These two atoms cannot be classified as isotopes of the same element because they do not have the same atomic number (Z).
   (b) This could be a "beta particle" radioisotope and its decay product, where there has been a conversion of two neutrons into two protons and two electrons. The result is that the mass number stays the same, but the number of protons — the atomic number — increases.
4. The usual classifying properties of nonradioactive elements are physical and chemical properties. The property of radioactivity — or radioactive decay — is a property that can be used to classify atoms of an element that can spontaneously change into atoms of another element. The classifying property of radioactivity is different in that it describes a nuclear change.

Applying Inquiry Skills

5. (a)



   (b) The above graph isolates the radioactive decay of thorium-234 through the lower mass values. For 24.0 g of thorium-234 to remain, approximately 4 half-lives and about 90% of a fifth half-life must pass — a total of 118.2 d.

Making Connections

6. (a) Radioisotopes are useful for diagnostic radiography, radiology, forensic anthropology, nuclear power, for killing bacteria in food and preventing spoilage, etc.
   (b) Safety precautions that may be used when handling radioisotopes include:
   - minimize the dose by reducing time of exposure
   - minimize the dose by maximizing the distance from the source
   - use shielding (common materials are lead, iron, concrete, and water) both for containment and for protective clothing
   - control access to the radioactive material
   - conduct frequent surveys of contact
   - conduct follow-up bioassays, looking for tissue damage
   - wear respiratory protection
   - practise good housekeeping; treat any waste from the lab as if it were radioactive

1.4 TOWARD A MODERN ATOMIC THEORY

PRACTICE

(Page 42)

Understanding Concepts

1. Bohr proposed the following explanation for the emission of light when a gas is heated: When energy (heat or electricity) is supplied to hydrogen atoms, electrons gain a certain quantity of energy and become excited (they jump from