Chapter 3—Minerals: The Building Blocks of Rocks

ESSAY

1. Why are minerals important economically? What effect does the distribution of minerals have on the economic well-being of nations?

   ANS:
   Minerals and rocks are used for fertilizer and animal feed supplements, for energy, and for commodities. Nations that are rich in economically valuable minerals are likely to be economically successful, and the distribution of minerals, rocks, and energy resources affects foreign relations and the economic ties between nations.

   PTS: 1 REF: Introduction

2. What is the definition of a mineral, and what do each of the parts of the definition mean?

   ANS:
   A mineral is a naturally occurring, inorganic, crystalline solid with a narrowly defined chemical composition and characteristic physical properties. Naturally occurring: a manmade substance cannot be a mineral; inorganic: anything that was once alive cannot be a mineral; crystalline solid: constituent atoms are arranged in a three-dimensional framework; narrowly defined chemical composition: the chemistry of a mineral may vary but within a very specific range.

   PTS: 1 REF: Introduction

3. How do a rock and a mineral differ?

   ANS:
   A rock is a naturally occurring aggregate of minerals, while minerals are naturally occurring, inorganic crystalline solids. Rocks are made up of minerals, not vice versa.

   PTS: 1 REF: Introduction

4. Describe what matter is. What categories of things are considered matter? What are the four states of matter?

   ANS:
   Matter is anything that has mass and occupies space. Matter includes water, plants, animals, the atmosphere, minerals, and rocks. The four states of matter are liquids, gases, solids, and plasma.

   PTS: 1 REF: LO1 Matter: What Is It?

5. For each of the following subatomic particles, state where it can be found and what its charge is: proton, electron, and nucleus.

   ANS:
   Protons are found in the nucleus and have positive charge; electrons orbit the nucleus and have negative charge; and the nucleus is found in the center of the atom and has positive charge.

   PTS: 1 REF: LO1 Matter: What Is It?

6. What is atomic bonding, and what is the result of bonding? List the types of bonding and how common they are.

   ANS:
   Two or more atoms join together by bonding, resulting in a substance called a compound. The most common types of bonding are ionic and covalent. The less common types are metallic and van der Waals.

   PTS: 1 REF: LO1 Matter: What Is It?

7. What are radioactive isotopes, and why are they important to geologists?

   ANS:
   A radioactive isotope is one that undergoes spontaneous decay from one isotope of an element to another isotope of that same element, or even change to other elements. Radioactive isotopes are important for determining the absolute ages of rocks.

   PTS: 1 REF: LO1 Matter: What Is It?

8. The chemical formula of halite is NaCl. In simple terms, state how these atoms come together to form a solid mineral.

   ANS:
   Sodium has only one electron in its outer shell, whereas chlorine has seven. Atoms want to have a full outer shell, so sodium gives its extra electron to chlorine, creating two ions: Sodium now has a positive charge and is Na^+, and chlorine has a negative charge and is Cl^-. This is called ionic bonding.

   PTS: 1 REF: LO1 Matter: What Is It?

9. Discuss how carbon atoms come together to form diamond.

   ANS:
   The electron shells of adjacent carbon atoms overlap, and they share electrons. This is called covalent bonding. A carbon atom in diamond shares all four of its outer electrons with a neighbor.

   PTS: 1 REF: LO1 Matter: What Is It?

10. What is the main feature of metallic bonding, and what properties result from this main feature?

    ANS:
    In metals, electrons in the outermost electron shells can move freely from one atom to another. The movement of electrons accounts for the metals metallic luster, electrical and thermal conductivity, and ease of reshaping.

    PTS: 1 REF: LO1 Matter: What Is It?

11. Graphite and diamond are both made of carbon, but only one is good for pencil lead. Why is graphite useful for this task while diamond is not?

    ANS:

The carbon atoms in diamond are held together by covalent bonds; they share electrons so that each carbon atom has the noble gas configuration of eight electrons in its outermost electron shell. Diamond is very strong. The carbon atoms in graphite are covalently bonded to form sheets, so the sheets are internally strong but are held together by weak van der Waals bonds. Small pieces of graphite can flake off along planes when a pencil is run across a piece of paper.

PTS: 1 REF: LO1 Matter: What Is It?

12. Why do some minerals form regular crystals and some do not? Even the same mineral, like quartz, may form beautiful crystals or irregular blobs.

ANS:
While all minerals are crystalline solids in which their atoms are arranged in a three-dimensional framework, some minerals grow to possess planar surfaces, sharp corners, and straight edges because they have space to grow into their crystal form. Minerals that do not form crystals grow in proximity with other crystals and do not have space to form a regular crystal.

PTS: 1 REF: LO1 Matter: What Is It?

13. What does the constancy of interfacial angles refer to? How did Nicholas Steno explain his observation?

ANS:
Nicholas Steno in 1669 determined that the angles of intersection of equivalent crystal faces on different specimens of the same mineral are identical. He postulated that mineral crystals are made up of very small, identical building blocks and that the arrangement of these building blocks determines the external form of the crystals.

PTS: 1 REF: LO2 Explore the World of Minerals

14. Why do some minerals have a fixed chemical composition and some have a range of compositions? Give an example of a mineral with a range of compositions.

ANS:
In many minerals, the chemical composition does not vary. In some minerals, one element can substitute for another if the atoms of the two elements are nearly the same size and the same charge. In olivine, magnesium and iron can both fill the cation position, so the chemical composition for the mineral is $(Mg, Fe)_2SiO_4$.

PTS: 1 REF: LO2 Explore the World of Minerals

15. Name and draw one example for each of the following types of tetrahedra: isolated tetrahedra, single chain tetrahedra, double chain tetrahedra, sheet tetrahedra, and framework tetrahedra

ANS:
Olivine, pyroxene, amphibole, biotite/muscovite/mica/clay, quartz/feldspar.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

16. What is the chemical structure of all silicate minerals, and why are silicate minerals so important?

ANS:
All silicate minerals contain silica, which is made of one silicon and oxygen. Silicate minerals include about one-third of all minerals; together they make up 95% of Earth's crust.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

17. Describe the Mohs hardness scale and list, in increasing order of hardness, the minerals of the Mohs hardness scale.

ANS:
The Mohs hardness scale measures a mineral's resistance to abrasion and is controlled mostly by its internal structure. The minerals of the scale from softest to hardest are: talc, gypsum, calcite, fluorite, apatite, orthoclase/feldspar, quartz, topaz, corundum, and diamond.

PTS: 1 REF: LO4 Physical Properties of Minerals

18. How are fracture and cleavage the same, and how are they different?

ANS:
Not all minerals possess cleavage, but those that do can have cleavage of varying quality. Minerals can possess more than one direction of cleavage. Cleavage is an important diagnostic property of minerals because it reveals the underlying chemical structure of the mineral. Some minerals can be told apart primarily by their different cleavage. Fracture occurs any time enough force is applied to a mineral and it does not make a regular shape.

PTS: 1 REF: LO4 Physical Properties of Minerals

19. In what two ways do minerals form from magma? What types of minerals dominate the minerals that make up igneous rocks?

ANS:
As magma cools, minerals crystallize and grow. Basalts are dominated by ferromagnesian minerals and granites by nonferromagnesian minerals. Hot water solutions derived from the magma invade cracks in adjacent rocks and then crystallize.

PTS: 1 REF: LO6 How Do Minerals Form?

20. What makes a resource into a reserve? What is the distinction between them, and what factors does it depend on?

ANS:
Resources are concentrations of a useful commodity that may be known or unknown. A reserve is the part of the resource that is known and can be economically recovered. There are several factors that may make a resource into a reserve, including geographic location, the value of the commodity, the distance of the commodity from where it will be used, the market price, and the technology available for recovering the commodity.

PTS: 1 REF: LO7 Natural Resources and Reserves

SHORT ANSWER

1. What is a rock?

ANS:
A rock is a naturally occurring aggregate of one or more minerals.

PTS: 1 REF: Introduction

2. Name three properties commonly exhibited by minerals that have metallic bonding.

   ANS:
   Choose any three of the following: metallic luster, electrical conductivity, thermal conductivity, higher specific gravity, and malleability.

   PTS: 1 REF: LO1 Matter: What Is It?

3. Name one property commonly exhibited by minerals that have van der Waals bonding.

   ANS:
   Flakiness, such as with graphite.

   PTS: 1 REF: LO1 Matter: What Is It?

4. Diamond and graphite are two minerals with the same chemical composition, but extremely different physical properties. Why is this?

   ANS:
   They have different crystal structures.

   PTS: 1 REF: LO1 Matter: What Is It?

5. What is meant when minerals are referred to as "crystalline solids?"

   ANS:
   The constituent atoms are arranged in a regular, three-dimensional pattern.

   PTS: 1 REF: LO2 Explore the World of Minerals

6. What is the most common mineral group, and what are three common examples?

   ANS:
   Silicates: quartz, feldspar, olivine.

   PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

7. What are the eight chemical elements that make up over 99% of Earth's crust?

   ANS:
   O, Si, Al, Fe, Mg, Ca, Na, and K.

   PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

8. How many minerals have been identified and described?

   ANS:
   More than 3,500.

   PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

9. How many minerals are common?

ANS:
Approximately two dozen.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

10. Why do most minerals, as measured by rock volume, belong to the silicate group?

ANS:
Because oxygen and silicon are the two most abundant elements in the crust.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

11. Give an example of a ferromagnesian silicate.

ANS:
Olivine/pyroxene/amphibole/biotite.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

12. Give an example of a nonferromagnesian silicate.

ANS:
Quartz/feldspar/muscovite/clay.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

13. Give one example of each of the carbonates, sulfates, sulfides, and halides.

ANS:
Calcite/dolomite, gypsum, pyrite/sphalerite/galena, halite/fluorite.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

14. Give an example of a native element.

ANS:
Gold/silver/copper/diamond/graphite.

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

15. What is a simple chemical test that will distinguish calcite from non-carbonate minerals?

ANS:
Calcite will effervesce in hydrochloric acid, while the others will not.

PTS: 1 REF: LO4 Physical Properties of Minerals

16. What is the most distinctive physical property of the mineral halite?

ANS:
The salty taste.

PTS: 1 REF: LO4 Physical Properties of Minerals

17. If a diamond is the hardest naturally occurring substance, how can one be "cut"?

    ANS:
    It is actually cleaved, along one of its four directions.

    PTS: 1 REF: LO4 Physical Properties of Minerals

18. What is a rock-forming mineral?

    ANS:
    A mineral that is sufficiently common in a type of rock that it can be used for identification and classification of that rock type.

    PTS: 1 REF: LO5 Rock-Forming Minerals

19. Name three factors that determine whether a known mineral resource in an area can become a reserve.

    ANS:
    Any three of the following: market price/technology/cost (e.g., labor, transportation, location).

    PTS: 1 REF: LO7 Natural Resources and Reserves

20. How does a mineral reserve differ from a mineral resource?

    ANS:
    A reserve is that part of a resource that can be extracted (mined) economically.

    PTS: 1 REF: LO7 Natural Resources and Reserves

COMPLETION

1. Carbon-12 (C^{12}), carbon-13 (C^{13}), and carbon-14 (C^{14}) are all _____ of the _____ carbon.

   ANS: isotopes, element

   PTS: 1 REF: LO1 Matter: What Is It?

2. In the center of an atom is its _____, which is composed of positively-charged particles called _____ and neutrally-charged particles called _____. This central part is orbited by negatively-charged particles called _____.

   ANS: nucleus, protons, neutrons, electrons

   PTS: 1 REF: LO1 Matter: What Is It?

3. Atoms of the same chemical element, carbon for example, always have the same number of _____ in the nucleus.

   ANS: protons

PTS: 1 REF: LO1 Matter: What Is It?

4. C^{12} has 6 protons. How many protons does C^{13} have? _____ How many neutrons does C^{13} have? _____ Nitrogen-14 (N^{14}) has 6 protons and 8 neutrons—true or false? _____

   ANS: 6, 7, false

   PTS: 1 REF: LO1 Matter: What Is It?

5. The atomic number of an atom is determined by the number of _____ in its nucleus.

   ANS: protons

   PTS: 1 REF: LO1 Matter: What Is It?

6. The atomic mass of an atom is defined as the sum of the number of its _____ plus _____.

   ANS: protons, neutrons

   PTS: 1 REF: LO1 Matter: What Is It?

7. Different isotopes of the same element differ from each other because they have different _____.

   ANS: atomic masses

   PTS: 1 REF: LO1 Matter: What Is It?

8. In the _____ type of chemical bonding, electrons are shared between adjacent atoms.

   ANS: covalent

   PTS: 1 REF: LO1 Matter: What Is It?

9. In the _____ type of chemical bonding, electrons are transferred between adjacent atoms.

   ANS: ionic

   PTS: 1 REF: LO1 Matter: What Is It?

10. The chemical formula $KAlS_3O_8$ means that the mineral orthoclase is composed of one atom of K and one of Al for every _____ of Si and _____ of O.

    ANS: three, eight

    PTS: 1 REF: LO2 Explore the World of Minerals

11. _____ and _____ are mineral compounds that are commonly produced by animals and are known as calcium _____.

ANS:
Calcite, aragonite, carbonate
Aragonite, calcite, carbonate

PTS: 1 REF: LO2 Explore the World of Minerals

12. The two factors which determine whether or not an element can substitute for another element in the composition of a mineral are the _____ and _____ of the atoms.

ANS:
size, charge
charge, size

PTS: 1 REF: LO2 Explore the World of Minerals

13. Minerals are chemically classified by their _____ or _____.

ANS:
negative ion, ion group
ion group, negative ion

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

14. Tightly bonded, complex groups of different atoms that act as single units (e.g., carbonate) are known as _____.

ANS: radicals

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

15. The basic building block of silicate minerals is the silica _____.

ANS: tetrahedron

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

16. The silicon atom of the silica tetrahedron has a (+/-) _____ charge of _____ (number?) and the oxygen atoms have a (+/-) _____ charge of _____ (number?). Therefore, the ion group has an overall (+/-) _____ charge of _____ (number?).

ANS: positive, four, negative, two, negative, four

PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

17. The ratio of a substance's weight, especially a mineral, to an equal volume of water at 4°C is called its _____.

ANS: specific gravity

PTS: 1 REF: LO4 Physical Properties of Minerals

18. The two basic types of luster are _____ and _____.

    ANS:
    metallic, nonmetallic
    nonmetallic, metallic

    PTS: 1 REF: LO4 Physical Properties of Minerals

19. The most abundant rock-forming minerals are the nonferromagnesian silicates called the _____.

    ANS: feldspars

    PTS: 1 REF: LO5 Rock-Forming Minerals

20. Resources that include sand, gravel, crushed stone, salt, and sulfur are known as _____ resources.

    ANS: nonmetallic

    PTS: 1 REF: LO7 Natural Resources and Reserves

MULTIPLE CHOICE

1. Which of the following is *not* true of minerals? They are(have):
   a. crystalline.
   b. organic.
   c. naturally occurring.
   d. definite chemical composition.
   e. characteristic physical properties.

   ANS: B PTS: 1 REF: Introduction

2. An atom is:
   a. a negatively-charged particle that circles a nucleus.
   b. a positively-charged particle within a nucleus.
   c. the smallest particle into which an element can be divided while still retaining the chemical characteristics of that element.
   d. a combination of elements.
   e. a negatively-charged particle that orbits the nucleus.

   ANS: C PTS: 1 REF: LO1 Matter: What Is It?

3. The relatively massive, positively-charged particles in the nucleus of an atom are:
   a. protons.
   b. neutrons.
   c. electrons.
   d. megatrons.
   e. none of the above

   ANS: A PTS: 1 REF: LO1 Matter: What Is It?

4. Isotopes of the same element have:
   a. different numbers of protons but the same number of neutrons.

b. the same number of electrons and different numbers of neutrons.
c. different numbers of neutrons but the same number of protons.
d. different numbers of electrons but the same number of neutrons.
e. none of the above

ANS: C PTS: 1 REF: LO1 Matter: What Is It?

5. Ionic bonds occur when electrons:
a. are transferred between atoms.
b. are shared by atoms.
c. have a neutral charge.
d. have a positive charge.
e. none of the above

ANS: B PTS: 1 REF: LO1 Matter: What Is It?

6. Covalent bonds differ from ionic bonds in that:
a. ionic bonds arise from electrical attraction between positively- and negatively-charged ions.
b. covalent bonds arise from the sharing of one or more electrons.
c. covalent bonds can occur between atoms of the same element.
d. A and B only
e. A, B, and C

ANS: E PTS: 1 REF: LO1 Matter: What Is It?

7. For a neutrally-charged atom to become a positively-charged atom of the same element, it must:
a. lose a proton.
b. lose an electron.
c. gain a proton.
d. gain an electron.
e. none of the above

ANS: B PTS: 1 REF: LO1 Matter: What Is It?

8. A neutrally-charged atom that becomes a positively-charged atom of the same element can be called a(n):
a. positron.
b. neutron.
c. ion.
d. isotope.
e. none of the above

ANS: C PTS: 1 REF: LO1 Matter: What Is It?

9. Elements bond together to form molecules because they:
a. are most stable when their outer electron shell is filled.
b. need to have a positive charge.
c. need to have a negative charge.
d. are glued together by positrons.
e. none of the above

ANS: A PTS: 1 REF: LO1 Matter: What Is It?

10. Cleavage is defined as:
a. planes of fracture resulting from weak bonds.

b. smooth, flat reflective surfaces.
c. surfaces of smooth, curved fracture.
d. planes of fracture resulting from strong bonds.
e. none of the above

ANS: A PTS: 1 REF: LO2 Explore the World of Minerals

11. Common examples of sulfide and sulfate minerals, respectively, are:
a. galena and pyrite.
b. gypsum and anhydrite.
c. galena and gypsum.
d. galena and hematite.
e. fluorite and pyrite.

ANS: C PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

12. Which of the following are all examples of minerals?
a. bronze, steel, glass, aluminum, pencil lead
b. gold, silver, uranium, lead, silica, iron
c. copper, ice, quartz, topaz, diamond, corundum
d. water, mercury, metallic hydrogen, limestone
e. petroleum, coal, iron, feldspar, basalt

ANS: C PTS: 1 REF: LO4 Physical Properties of Minerals

13. The primary occurrence of the rock-forming minerals olivine, pyroxene, and amphibole is:
a. igneous rocks.
b. metamorphic rocks.
c. sedimentary rocks.
d. A and B
e. all rock types

ANS: D PTS: 1 REF: LO5 Rock-Forming Minerals

14. Which of the following is an example of a mineral resource?
a. sand
b. gold
c. petroleum
d. salt
e. all of the above

ANS: E PTS: 1 REF: LO7 Natural Resources and Reserves

15. An example of a material that has been both a resource and a reserve, depending on abundance, economic conditions, and mining technology, is:
a. platinum.
b. gold.
c. petroleum.
d. iron.
e. all of the above

ANS: E PTS: 1 REF: LO7 Natural Resources and Reserves

TRUE/FALSE

1. Ice is a mineral, but snowflakes are not.

   ANS: F PTS: 1 REF: Introduction

2. Nearly all types of minerals are beautiful and valuable.

   ANS: F PTS: 1 REF: Introduction

3. All minerals are compounds.

   ANS: F PTS: 1 REF: LO1 Matter: What Is It?

4. Noble gases are chemically inert because their outer electron shell is filled.

   ANS: T PTS: 1 REF: LO1 Matter: What Is It?

5. van der Waals bonds occur between atoms or compounds without free electrons.

   ANS: T PTS: 1 REF: LO1 Matter: What Is It?

6. The number of neutrons in an atom always equals the number of protons.

   ANS: F PTS: 1 REF: LO1 Matter: What Is It?

7. The atomic mass of an atom may vary, but its atomic number does not.

   ANS: T PTS: 1 REF: LO1 Matter: What Is It?

8. Minerals may have chemical compositions that vary within a range.

   ANS: T PTS: 1 REF: LO2 Explore the World of Minerals

9. Native elements are among those that occur in concentrations known as ores.

   ANS: T PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

10. Olivine is an example of a mineral with isolated silica tetrahedra.

    ANS: T PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

11. Mica and clay minerals have a platy crystal form because they have a sheet-like structure of silica tetrahedra.

    ANS: T PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

12. Minerals of the amphibole group have their silica tetrahedra arranged in double chains.

    ANS: T PTS: 1 REF: LO3 Mineral Groups Recognized By Geologists

13. The best characteristic to use when identifying minerals is color.

    ANS: F PTS: 1 REF: LO4 Physical Properties of Minerals

14. A mineral's density is the ratio of its weight relative to the weight of an equal volume of pure water at 4°C.

    ANS: F PTS: 1 REF: LO4 Physical Properties of Minerals

15. The United States is self-sufficient in petroleum.

    ANS: F PTS: 1 REF: LO7 Natural Resources and Reserves