Chapter 1

Introduction to Chemistry

INSIGHT Critical Materials

1.1 Are the elements designated as critical materials all rare?
Explain your answer.

They are not all necessarily rare, but many are found in only a few locations around the world and as such are subject to supply disruptions.

1.2 In what country is most of the world's cobalt mined? What events in that country dramatically affected the price of cobalt?

The Democratic Republic of Congo produces most of the world's cobalt. Political unrest in that country once caused a 600% spike in the price of cobalt. Political instability continues as well as issues with forced child labor in the mining of cobalt.

1.3 In what types of technology do the elements designated as critical materials generally play important roles?

They are important in light emission, magnetism, and a variety of applications associated with clean energy and electronics.

1.4 Based on the information in Figure 1.1, which three elements would you argue are the most critical among the "critical materials"? Justify your answer.

Neodymium, dysprosium, and terbium. Neodymium and dysprosium have the highest ranking in importance for clean energy. Dysprosium and terbium are ranked highest in terms of potential supply risk.

1.5 In what region of the periodic table are most of the elements that are listed as critical materials found?

Most of the critical elements are located in the middle of the periodic table, specifically the region known as the lanthanide series and to a lesser extent the transition elements.

1.6 What agency of the U.S. government is responsible for identifying an element as a critical material? What sorts of applications are the primary concern of this agency?

The Department of Energy (DOE) and an organization that it manages called the Critical Materials Institute. Primary concerns are energy-related technologies, especially clean energy applications such as wind and solar energy and electric cars.

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The Study of Chemistry

1.7 When making observations in the laboratory, which perspective of chemistry are we normally using?

We make observations in the laboratory using the macroscopic perspective of chemistry, unless very sophisticated instruments are used.

1.8 Which of the following items are matter and which are not? **(a)** a flashlight, **(b)** sunlight, **(c)** an echo, **(d)** air at sea level, **(e)** air at the top of Mount Everest

(a) matter, (b) not matter, (c) not matter, (d) matter, (e) matter

1.9 Which macroscopic characteristics differentiate solids, liquids, and gases? (List as many as possible.)

Solids maintain a definite shape; liquids and gases do not. Gases expand to completely occupy their container; liquids assume the shape of the container but do not fully occupy it. Solids tend to have high densities, liquids usually slightly lower, and gases typically have very low densities, comparatively.

1.10 Do the terms *element* and *atom* mean the same thing? If not how do they differ?

No. An element is a pure substance, but the naturally occurring form of the element may contain more than one atom. An example of this is elemental nitrogen (N_2). In this case the element has two atoms.

1.11 Label each of the following as either a physical process or a chemical process: **(a)** rusting of an iron bridge, **(b)** melting of ice, **(c)** burning of a wooden stick, **(d)** digestion of a baked potato, **(e)** dissolving of sugar in water.

A chemical change involves a change in the *composition* of matter; that is, some new substances are formed. A physical change only involves a change in the *physical state* of matter; no new substances are formed.

(a) rusting of an iron bridge	**Chemical, rust forms when iron and oxygen react chemically.**
(b) melting of ice	**Physical, change from the solid to the liquid state.**
(c) burning of a wooden stick	**Chemical, the molecules in the wood are changed into carbon dioxide and water during combustion.**
(d) digestion of a baked potato	**Chemical, larger food molecules are changed into smaller ones and eventually oxidized (“burned”) to produce energy.**
(e) dissolving of sugar in water	**Physical, the sugar molecules are not changed they just become surrounded by water molecules in solution.**

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1.12 Why do physical properties play a role in chemistry if they do not involve any chemical changes?

Physical properties can be used to identify substances in qualitative and quantitative analysis and can provide a wide range of useful information.

1.13 Physical properties may change because of a chemical change. For example, the color of an egg "white" changes from clear to white because of a chemical change when it is cooked. What is another common situation in which a chemical change also leads to a physical change?

The "rusting" of iron is a chemical change. A chemical reaction changes the metal to a new compound. The rust formed is a brittle, orange-red compound with very different properties than iron.

1.14 Which part of the description of a compound or element refers to its physical properties and which to its chemical properties?

(a) Calcium carbonate is a white solid with a density of 2.71 g/cm^3. It reacts readily with an acid to produce gaseous carbon dioxide.
(b) Gray powdered zinc metal reacts with purple iodine to give a white compound.

(a) The first sentence describes physical properties; the second sentence describes a chemical property.
(b) The sentence generally describes a chemical property, however the stated colors are physical properties.

Observations and Models

1.15 We used the example of a football game to emphasize the nature of observations. Describe another example where deciding how to "count" subjects of interest could affect the observation.

The number of cities located in a state depends on how a city is defined. We would need to specify what population size is makes a city. Our results would vary depending on that size.

1.16 Complete the following statement: Data that have a small random error but otherwise fall in a narrow range are **(a)** accurate, **(b)** precise, or **(c)** neither.

These data could be precise but not necessarily accurate.

1.17 Complete the following statement: Data that have a large systematic error are (a) accurate, (b) precise, (c) neither.

(b) Precise. Data that have large systematic error may still be precise. Accuracy is how close our data is to the actual value. Large systematic error means the data will not be

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close to the actual value but they will be off by about the same amount. Precision is the repeatability of your data. Precise data will agree closely but may not be close to the true value.

1.18 Two golfers are practicing shots around a putting green. Each golfer takes 20 shots. Golfer 1 has 7 shots within 1 meter of the hole, and the other 13 shots are scattered around the green. Golfer 2 has 17 shots go into a small sand trap near the green and three just on the green near the trap. Which golfer is more precise? Which is more accurate?

Golfer 2 is more precise because his efforts are grouped more tightly about a central point (mean) even if it's not the intended spot. Golfer 1 is more accurate as there are more shots very close to the accepted "value" (the hole).

1.19 Use your own words to explain the difference between deductive and inductive reasoning.

In deductive reasoning, facts are considered and conclusions are drawn from this information. In inductive reasoning, you first infer what seems to be accurate or true, and then find ways to determine if later observations fit the inferred conclusion.

1.20 Suppose you are waiting at a corner for a bus. Three different routes pass this particular corner. You see busses pass by from the two routes you are not interested in taking. When you say to yourself, "My bus must be next," what type of reasoning (deductive or inductive) are you using? Explain your answer.

Deductive reasoning is being applied in this case. The first two buses represent pieces of information that are processed and lead to the conclusion that the "desired" bus must be next.

1.21 When a scientist looks at an experiment and then predicts the results of other related experiments, which type of reasoning is she using? Explain your answer.

This is inductive reasoning. Inductive reasoning is the reverse of deductive. A scientist makes predictions and then tries to prove the prediction by later observations. Deductive reasoning involves starting with facts and then drawing conclusions from those.

1.22 What is the difference between a hypothesis and a question?

A hypothesis is a statement related to observation(s). The hypothesis is either accepted or rejected based upon experimentation. A question is simply posed.

1.23 Should the words *theory* and *model* be used interchangeably in the context of science? Defend your answer using web information.

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The word "theory" implies something more advanced and supported than a model. When a model makes predictions and all observations are consistent with these observations, then the model may be described as a theory.

1.24 What is a law of nature? Are all scientific laws examples of laws of nature?

A law of nature is an irrefutable, self-evident fact. Not all scientific laws are examples of laws of nature.

Numbers and Measurements

1.25 Describe a miscommunication that can arise because units are not included as part of the information.

Discussing the time of day and omitting PM or AM. If you are supposed to meet someone at 9:00 but they didn't say in the evening or in the morning, the meeting might not occur. Another example might be negotiating a price while trying to buy something.

1.26 What is the difference between a qualitative and a quantitative measurement?

A quantitative measurement provides information as to *how much* analyte is present. A qualitative measurement answers the question, 'is the analyte present?'

1.27 Identify which of the following units are base units in the SI system: grams, meters, joules, liters, and amperes.

Meters and amperes are base units. The other base units are: kilograms, seconds, kelvins, moles, and candelas. Therefore grams are not a base unit. Joules and liters are both derived units.

1.28 What is a "derived" unit?

A derived unit is a unit that is made up of two or more base units.

1.29 Rank the following prefixes in order of increasing size of the number they represent: centi−, giga−, nano−, and kilo−.

In order of smallest to largest: nano− (10^{-9}), centi− (10^{-2}), kilo− (10^{3}), giga− (10^{9}).

1.30 The largest computers now include disk storage space measured in petabytes. How many bytes are in a petabyte? (Recall that in computer terminology, the prefix is only "close" to the value it designates in the metric system.)

1 petabyte = 1,000,000,000,000,000 bytes

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