Matter and Energy

3

Chapter Overview

The universe is made up of a finite amount of matter and energy. It is these two concepts that tie most chemical principles together. Therefore, we must have a very good understanding of these ideas to develop the more detailed topics later in the course. Temperature, states and properties of matter, and the associated calculations will be covered.

Lecture Outline

3.1 In Your Room
- A. What you see, touch, smell is all matter

3.2 What Is Matter?
- Learning Objective: Define matter, atoms, and molecules.
- A. Occupies space and has mass
- B. Atom – smallest unit of matter
- C. Molecule – atoms joined together

3.3 Classifying Matter According to Its State: Solid, Liquid, and Gas
- Learning Objective: Classify matter as solid, liquid, or gas.
- A. Solid
    1. Crystalline
    2. Amorphous
- B. Liquid
    1. Fixed volume
    2. Fluid
- C. Gas
    1. Compressible
    2. Fluid

3.4 Classifying Matter According to Its Composition: Elements, Compounds, and Mixtures
- Learning Objective: Classify matter as element, compound, or mixture.
- A. Pure substance
    1. Composed of one type of atom or molecule
    2. Elements or compounds
- B. Mixture
    1. Composed of two or more types of atoms or molecules
    2. Homogeneous or heterogeneous

3.5 Differences in Matter: Physical and Chemical Properties
- Learning Objective: Distinguish between physical and chemical properties.
- A. Physical property
    1. Observable without changing the identity
    2. Examples: melting point, odor, color

B. Chemical property
1. Observable only by changing the identity
2. Example: flammability

3.6 Changes in Matter: Physical and Chemical Changes
Learning Objective: Distinguish between physical and chemical changes.
A. Physical change
1. Appearance and properties can change
2. Composition does not change
B. Chemical change
1. Appearance and properties can change
2. Composition changes
C. Separation of mixtures through physical changes
1. Decanting
2. Distillation
3. Filtration

3.7 Conservation of Mass: There Is No New Matter
Learning Objective: Apply the law of conservation of mass.
A. Matter is neither created nor destroyed in a chemical reaction
B. Mass sum of chemicals before reaction is the same as after

3.8 Energy
Learning Objective: Recognize the different forms of energy.
Learning Objective: Identify and convert among energy units.
A. Energy cannot be created or destroyed
B. Forms of energy
1. Kinetic – energy of motion
2. Potential – energy associated with position
3. Electrical – energy from the flow of electron charge
4. Thermal – energy from random motions of atoms and molecules
5. Chemical – energy associated with potential chemical change
C. Units of energy
1. Joule (J)
2. calorie (cal)
3. Calorie (Cal)
4. Kilowatt-hour (kWh)

3.9 Energy and Chemical and Physical Change
Learning Objective: Distinguish between exothermic and endothermic reactions.
A. Exothermic reaction: molecules release energy to surroundings
B. Endothermic reaction: molecules absorb energy from surroundings

3.10 Temperature: Random Motion of Molecules and Atoms
Learning Objective: Convert between Fahrenheit, Celsius, and Kelvin temperature scales.
A. Fahrenheit (°F)
B. Celsius (°C)
C. Kelvin (K)

3.11 Temperature Changes: Heat Capacity
Learning Objective: Relate energy, temperature change, and heat capacity.
A. How much energy is required to change the temperature of a substance
B. Varies from one substance to another
C. Metals have low heat capacity, water has a high heat capacity
D. Units: J/g°C

3.12 Energy and Heat Capacity Calculations

Learning Objective: Perform calculations involving transfer of heat and changes in temperature.

A. Heat = mass × heat capacity × temperature change

B. Heat capacity is a conversion factor between temperature change, heat, and mass

Chemical Principle Teaching Ideas

Matter

Try to have the students come up with something that is NOT matter, and they will quickly realize that everything around them is matter.

Classification of Matter

A good exercise in classifying matter into certain categories is to point around the room, asking students what each object is and what group it falls under. There are plenty of examples of each grouping in a classroom; even the human body has some of each category.

Properties and Changes of Matter

Try listing various changes and ask the students if the changes are physical or chemical. List some measurable properties and ask students to classify them as physical or chemical changes.

Conservation of Mass

Some students will say that this is not true, as in a nuclear reaction where mass is converted into energy. Explain to them that this law is for chemical reactions, where no nuclear changes take place.

Energy

The total energy in the universe is constant, but the universe is expanding at a furious pace. You can use this opportunity to talk about the universe, how it was born, and its history.

Temperature

To help students understand why we have different temperature scales, you can discuss the origin of each scale. The Fahrenheit scale is based on the average temperature of the human body being at 100 °F (it was off a little bit) and the freezing point of a salt-ice bath of 0 °F. The Celsius scale is based on the freezing point and boiling point of pure water as 0° and 100° Celsius, respectively. The Kelvin scale is based on the coldest temperature that is possible, the temperature at which molecular motion ceases, and is set as 0 K.

Heat Capacity

One easy way for students to remember the concept of heat capacity and its relative magnitude is for them to look at water heating on a stove. Most of them will agree that if you put an empty metal pot on a stove the pot will get hot very quickly. However, if we fill the pot with water, it will take a very long time for the water to get to the same temperature. If they remember this scenario, they should remember that metals have a low heat capacity and water has quite a high heat capacity.

Skill Builder Solutions

3.1. a. Mercury is a pure substance and is also an element.
b. Exhaled air is a mixture of nitrogen, carbon dioxide, oxygen, and some other gases. The mixture is the same composition throughout, so it is a homogeneous mixture.
c. Soup is also a mixture, but each bite can taste different, so the mixture is not the same throughout. It is therefore a heterogeneous mixture.
d. Sugar is a pure substance and also a compound, as sugar is a molecule.

3.2. a. Hydrogen burns in oxygen to give water as a product. This is a chemical change, so it is a chemical property.
b. Observing the color of copper does not require that changes be made to the copper, so it is a physical property.
c. Luster (shininess) is a physical property associated with the smoothness of the metal surface.
d. Phase changes do not alter composition, so this is a physical property.

3.3. a. This is a chemical reaction involving copper solid becoming copper ion.
b. Since the penny is just getting a new shape, that is a physical change.
c. Phase changes like this solid-to-liquid change are physical changes.
d. Fireworks involve combustion, which is a chemical change.

3.4. 12 g gas + 48 g oxygen = 60 g of reactants. 33 g of carbon dioxide formed, so 60 g – 33 g = 27 g of water is produced.

3.5. $512\ \cancel{\text{cal}} \times \frac{4.184\ \cancel{\text{J}}}{1\ \cancel{\text{cal}}} \times \frac{1\ \text{kJ}}{1000\ \cancel{\text{J}}} = 2.14\ \text{kJ}$

Plus. $2.75\times10^{4}\ \cancel{\text{kJ}} \times \frac{1000\ \cancel{\text{J}}}{1\ \cancel{\text{kJ}}} \times \frac{1\ \text{cal}}{4.184\ \cancel{\text{J}}} = 6.57\times10^{6}\ \text{cal}$

3.6. a. Potential energy must be removed from liquid water to turn it into ice, so it is an exothermic reaction.
b. All combustion reactions are exothermic, releasing energy to the surroundings.

3.7. $358 - 273 = 85\ °\text{C}$

3.8. $[139 \times 1.8] + 32 = 282\ °\text{F}$

3.9. $\frac{(-321-32)}{1.8} + 273 = 77\ \text{K}$

3.10. $\left(3.10\ \cancel{\text{g}}\right)\left(42.0\ \cancel{°\text{C}}\right)\left(\frac{0.385\ \text{J}}{\cancel{\text{g}}\ \cancel{°\text{C}}}\right) = 50.1\ \text{J}$

Plus. $\frac{11.3\ \cancel{\text{J}}}{\left(12\ \cancel{°\text{C}}\right)\left(\frac{0.128\ \cancel{\text{J}}}{\text{g}\ \cancel{°\text{C}}}\right)} = 7.4\ \text{g}$

3.11. $$\Delta T = \frac{5.78\times10^{3}\ \cancel{J}}{(328\ \cancel{g})\left(\frac{4.184\ \cancel{J}}{\cancel{g}\ ^{\circ}C}\right)} = 4.21\ ^{\circ}C \quad T_f = 25.0 + \Delta T = 29.2\ ^{\circ}C.$$

Suggested Demonstrations

Heat and Dilution of Sulfuric Acid, *Chemical Demonstrations* 1:17, Shakhashiri, B. Z. University of Wisconsin Press, 1983.

Heat of Solution of Lithium Chloride, *Chemical Demonstrations* 1:21, Shakhashiri, B. Z. University of Wisconsin Press, 1983.

Burning of Magnesium, *Chemical Demonstrations* 1:38, Shakhashiri, B. Z. University of Wisconsin Press, 1983.

Dehydration of Sugar by Sulfuric Acid, *Chemical Demonstrations* 1:77, Shakhashiri, B. Z. University of Wisconsin Press, 1983.

Collapsing Can, *Chemical Demonstrations* 2:6, Shakhashiri, B. Z. University of Wisconsin Press, 1985.

Liquid Vapor Equilibrium, *Chemical Demonstrations* 2:75, Shakhashiri, B. Z. University of Wisconsin Press, 1985.

Guided Inquiry Ideas

Below are a few example questions that students answer in the guided inquiry activities provided in the Guided Activity Workbook.

How much energy do you think it will take to raise the temperature of 1 g of water from room temperature (about 20 °C) to body temperature (about 37 °C)? Explain your answer.

If you drink 1 cup (about 250 g) of ice water that is initially at 0 °C, how much energy will your body have to use to warm it up to body temperature?

An experiment was done in which 58 g of butane (enough for about a dozen lighters) was found to consume 208 g of oxygen when it burned. The products were 176 g of carbon dioxide and 90 g of water.

During the reaction, what changed?

During the reaction what did not change?