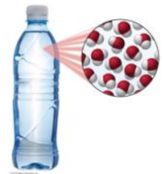
Slide 1

Chapter 2 Matter and Energy

1

2.1
Classification of Matter



Slide 2

Matter

2

Matter

- is the material that makes up all things
- is anything that has mass and occupies space

Brass (copper and zinc)
(c)

Slide 3

Pure Substances

3

A **pure substance** is classified as

- a type of matter with a fixed or definite composition
- an **element** that is composed of one type of atom
- a **compound** that is composed of two or more elements always combined in the same proportion

Slide 4

Elements

4

Elements

- are pure substances that contain only one type of material
- include
  - copper, Cu
  - lead, Pb
  - aluminum, Al

Copper
(a)

The element copper consists of copper atoms.

Slide 5

Compounds

5

A **compound**

- contains two or more elements in a definite ratio, such as
  hydrogen peroxide (H_2O_2)
  table salt ($NaCl$)
  sugar ($C_{12}H_{22}O_{11}$)
  water (H_2O)

Slide 6

Elements in a Compound

6

"Table salt" is a compound that contains the elements sodium and chlorine.

The decomposition of salt, NaCl, produces the elements sodium and chlorine.

Slide 7

Mixtures

7

A **mixture** is a type of matter that consists of

- two or more substances that are physically mixed but not chemically combined
- two or more substances in different proportions
- substances that can be separated by physical methods

A mixture of a liquid and a solid is separated by filtration.

Slide 8

Homogeneous Mixtures

8

In a **homogeneous mixture**,

- the composition is uniform throughout
- the different parts of the mixture are not visible

Brass (copper and zinc)
(c)

Brass is a homogeneous mixture of copper and zinc atoms.

Slide 9

Scuba Breathing Mixtures

9

Breathing mixtures for scuba are homogeneous mixtures. Some examples are

- Nitrox (oxygen and nitrogen gases)
- Heliox (oxygen and helium gases)
- Trimix (oxygen, helium, and nitrogen gases)

A Nitrox mixture is used to fill scuba tanks.

Slide 10

Heterogeneous Mixtures

10

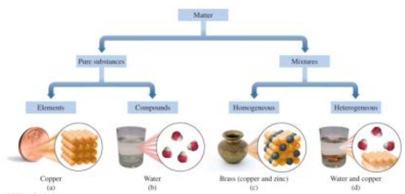
In a **heterogeneous mixture**,
- the composition varies from one part of the mixture to another
- the different parts of the mixture are visible

Oil and water form a heterogeneous mixture.

Slide 11

Classification of Matter

11



Slide 12

Learning Check

12

Identify each of the following as a pure substance or a mixture:

A. pasta and tomato sauce
B. aluminum foil
C. helium
D. air

Slide 13

Solution

13

Identify each of the following as a pure substance or a mixture:

A. pasta and tomato sauce	mixture
B. aluminum foil	pure substance
C. helium	pure substance
D. air	mixture

Slide 14

Learning Check

14

Identify each of the following as a homogeneous or heterogeneous mixture:

A. hot fudge sundae

B. shampoo

C. sugar water

D. peach pie

Slide 15

Solution

15

Identify each of the following as a homogeneous or heterogeneous mixture:

A. hot fudge sundae	heterogeneous mixture
B. shampoo	homogeneous mixture
C. sugar water	homogeneous mixture
D. peach pie	heterogeneous mixture

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Chapter 2 Matter and Energy

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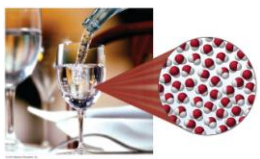
2.2
States and Properties of Matter



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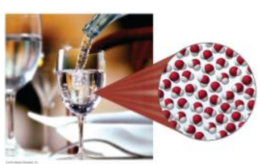
Properties of Matter

18

Matter has characteristics called physical and chemical properties.



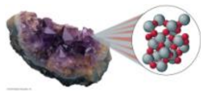
Slide 19

Solids

19

Solids have

- a definite shape
- a definite volume
- particles that are close together in a fixed arrangement
- particles that move very slowly



Amethyst, a solid, is a purple form of quartz (SiO_2).

Slide 20

Liquids

20

Liquids have

- an indefinite shape, but a definite volume
- the same shape as their container
- particles that are close together, but mobile
- particles that move slowly

A liquid has a definite volume, but takes the shape of its container.

Slide 21

Gases

21

Gases have

- an indefinite shape
- an indefinite volume
- the same shape and volume as their container
- particles that are far apart
- particles that move very fast

A gas takes the shape and volume of its container.

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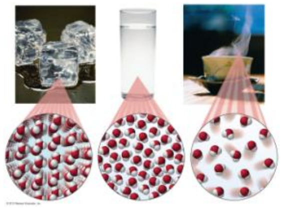
Three States of Matter for Water

22



The three states of matter are solid, liquid, and gas.

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Summary of the States of Matter

23

TABLE 2.1 A Comparison of Solids, Liquids, and Gases

Characteristic	Solid	Liquid	Gas
Shape	Has a definite shape	Takes the shape of the container	Takes the shape of the container
Volume	Has a definite volume	Has a definite volume	Fills the volume of the container
Arrangement of particles	Fixed, very close	Random, close	Random, far apart
Interaction between particles	Very strong	Strong	Essentially none
Movement of particles	Very slow	Moderate	Very fast
Examples	Ice, salt, iron	Water, oil, vinegar	Water vapor, helium, air

Slide 24

Learning Check

24

Identify each description as particles of a
1) solid 2) liquid 3) gas

__ A. definite volume, but takes the shape of the container
__ B. particles are moving rapidly
__ C. particles fill the entire volume of a container
__ D. particles have a fixed arrangement
__ E. particles are close together, but moving randomly

Slide 25

Solution

25

Identify each description as particles of a
1) solid 2) liquid 3) gas

A. 2 definite volume, but takes the shape of the container
B. 3 particles are moving rapidly
C. 3 particles fill the entire volume of a container
D. 1 particles have a fixed arrangement
E. 2 particles are close together, but moving randomly

Slide 26

Physical Properties

26

Physical properties

- are characteristics observed or measured without changing the identify of a substance
- include shape, physical state, boiling and freezing points, density, and color of that substance

Slide 27

Physical Properties of Copper

27

Copper has these physical properties:

- reddish-orange color
- shiny
- excellent conductor of heat and electricity
- solid at 25 °C
- melting point 1083 °C
- boiling point 2567 °C

Copper, used in cookware, is a good conductor of heat.

Slide 28

Learning Check

28

Identify the state of matter for each of the following:

A. vitamin tablets
B. eye drops
C. vegetable oil
D. a candle
E. air in a tire

Slide 29

Solution

29

Identify the state of matter for each of the following:

A. vitamin tablets	solid
B. eye drops	liquid
C. vegetable oil	liquid
D. a candle	solid
E. air in a tire	gas

Slide 30

Physical Change

30

A **physical change** occurs in a substance if there is

- a change in the state
- a change in the physical shape
- no change in the identity and composition of the substance

In a physical change, a gold ingot is hammered to form gold leaf.

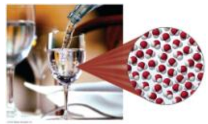
Slide 31

Examples of Physical Changes

31

Examples of **physical changes**:

- paper torn into little pieces (change of size)
- gold hammered into thin sheets of gold leaf (change of shape)
- water poured into a glass (change of shape)



Water as a liquid takes the shape of its container.

Slide 32

Learning Check

32

Classify each of the following as a
1) change of state 2) change of shape
A. chopping a log into kindling wood
B. water boiling in a pot
C. ice cream melting
D. ice forming in a freezer
E. cutting dough into strips

Slide 33

Solution

33

Classify each of the following as a
1) change of state 2) change of shape
A. (2) chopping a log into kindling
B. (1) water boiling in a pot
C. (1) ice cream melting
D. (1) ice forming in a freezer
E. (2) cutting dough into strips

Slide 34

Chemical Properties and Changes

34

Chemical properties describe the ability of a substance
- to interact with other substances
- to change into a new substance

When a **chemical change** takes place, the original substance is turned into one or more new substances with new chemical and physical properties.

Slide 35

Chemical Change

35

During a **chemical change**, a new substance forms that has
- a new composition
- new chemical properties
- new physical properties

Sugar caramelizing at a high temperature is an example of a chemical change.

Slide 36

Some Chemical Changes

36

Silver tarnishes Shiny metal reacts to form a black, grainy coating.

Wood burns A piece of wood burns with a bright flame to form ash, carbon dioxide, water vapor, and heat.

Iron rusts A shiny nail combines with oxygen to form orange-red rust.

Slide 37

Learning Check

37

Classify each of the following properties as physical or chemical:

A. ice melts in the Sun
B. copper is a shiny metal
C. paper can burn
D. a silver knife can tarnish
E. a magnet removes iron particles from a mixture

Slide 38

Solution

38

Classify each of the following properties as physical or chemical:

A. ice melts in the Sun (physical)
B. copper is a shiny metal (physical)
C. paper can burn (chemical)
D. a silver knife can tarnish (chemical)
E. a magnet removes iron particles from a mixture (physical)

Slide 39

Learning Check

39

Classify each of the following changes as physical or chemical:

A. burning a candle
B. ice melting on the street
C. toasting a marshmallow
D. cutting a pizza
E. iron rusting in an old car

Slide 40

Solution

40

Classify each of the following changes as physical or chemical:

A. burning a candle (chemical)
B. ice melting on the street (physical)
C. toasting a marshmallow (chemical)
D. cutting a pizza (physical)
E. iron rusting in an old car (chemical)

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Slide 42

Chapter 2 Matter and Energy

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2.3
Energy

Slide 43

Energy

43

Energy

- makes objects move
- makes things stop
- is needed to "do work"

When water flows from the top of a dam, potential energy is converted to kinetic energy.

Slide 44

Work

44

Work is done when

- you climb
- you lift a bag of groceries
- you ride a bicycle
- you breathe
- your heart pumps blood
- water goes over a dam

At the top of the rock, a climber has more potential energy than when she started the climb.

Slide 45

Potential Energy

45

Potential energy is energy stored for use at a later time.

Examples are

- water behind a dam
- a compressed spring
- chemical bonds in gasoline, coal, or food

Diesel fuel reacts in a car engine to produce energy.

Slide 46

Kinetic Energy

46

Kinetic energy is the energy of matter in motion.

Examples are

- swimming
- water flowing over a dam
- working out
- burning gasoline

When water flows from the top of a dam, potential energy is converted to kinetic energy.

Slide 47

Learning Check

47

Identify the energy in each example as potential or kinetic:

A. rollerblading
B. a peanut butter and jelly sandwich
C. mowing the lawn
D. gasoline in the gas tank

Slide 48

Solution

48

Identify the energy in each example as potential or kinetic:

A. rollerblading (kinetic)
B. a peanut butter and jelly sandwich (potential)
C. mowing the lawn (kinetic)
D. gasoline in the gas tank (potential)

Slide 49

Units for Measuring Energy or Heat

49

Heat is measured in joules or calories. The SI unit of energy is the **joule (J)**. The unit **calorie** is the amount of energy needed to raise the temperature of 1 g of water by 1 °C.

4.184 joules (J) = 1 calorie (cal)

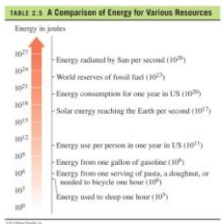
1 kJ = 1000 J

1 kilocalorie (kcal) = 1000 calories (cal)

Slide 50

Examples of Energy in Joules

50



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Learning Check

51

How many cal are obtained from a pat of butter if it provides 150 J of energy when metabolized?

A. 0.36 cal

B. 36 cal

C. 630 cal

Slide 52

Solution

52

How many cal are obtained from a pat of butter if it provides 150 J of energy when metabolized?

Step 1 State given and needed quantities.

Given: 150 J **Need:** calories

Step 2 **Plan:** J → cal

Step 3 Equalities/Conversion factor 1 calorie = 4.184 J

$\frac{1\ \text{cal}}{4.184\ \text{J}}$ and $\frac{4.184\ \text{J}}{1\ \text{cal}}$

Step 4 Set up problem.

$150\ \cancel{\text{J}} \times \frac{1\ \text{cal}}{4.184\ \cancel{\text{J}}} = 36\ \text{cal}$ The answer is B.

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Slide 54

Chapter 2 Matter and Energy

54

2.4 Temperature

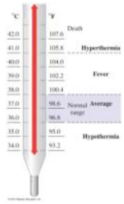
Slide 55

Temperature

55

Temperature

- is a measure of how hot or cold an object is compared to another object
- indicates the heat flow from the object with a higher temperature to the object with a lower temperature
- is measured using a thermometer



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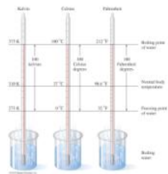
Temperature Scales

56

The **temperature scales**

- are Fahrenheit, Celsius, and Kelvin
- have reference points for the boiling and freezing points of water



A comparison of the Fahrenheit, Celsius, and Kelvin temperature scales between the freezing and boiling points of water.

Slide 57

Learning Check

57

A. What is the temperature at which water freezes?
1) 0 °F 2) 0 °C 3) 0 K

B. What is the temperature at which water boils?
1) 100 °F 2) 32 °F 3) 373 K

C. How many Celsius units are between the boiling and freezing points of water?
1) 100 2) 180 3) 273

Slide 58

Solution

A. What is the temperature at which water freezes?
  2) 0 °C

B. What is the temperature at which water boils?
  3) 373 K

C. How many Celsius units are between the boiling and freezing points of water?
  1) 100

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Fahrenheit – Celsius Formula

- On the **Fahrenheit scale**, there are 180 °F between the freezing and boiling points; on the **Celsius scale** there are 100 °C.

$$\frac{180\ °F}{100\ °C} = \frac{9\ °F}{5\ °C} = \frac{1.8\ °F}{1\ °C}$$

- In the formula for calculating the **Fahrenheit temperature**, adding 32 adjusts the zero point of water from 0 °C to 32 °F.

$$T_F = 1.8T_C + 32$$

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Temperature Math: Converting °C to °F

The temperature equation involves the exact numbers 1.8 and 32. Only the temperature is measured. To convert °C to °F, a multiplication rule is followed by an addition rule.

Multiplication step

1.8(–10. °C) = –18 °F (2 SFs)

Addition step

– 18 °F	ones place
+ 32	exact
= 14 °F	ones place

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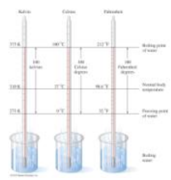
Solving a Temperature Problem

61

Hypothermia may occur when body temperature drops below 35 °C (95 °F).

A person with hypothermia has a body temperature of 34.8 °C. What is that temperature in °F?



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Solving a Temperature Problem

62

A person with hypothermia has a body temperature of 34.8 °C. What is that temperature in ° F?

Step 1 State given and needed quantities.

Given: 34.8 °C **Need:** T_F

Step 2 **Plan:** $T_C \longrightarrow T_F$

Step 3 Equality/Conversion factor

$T_F = 1.8T_C + 32$

Step 4 Set up problem.

$T_F = 1.8(34.8\ °C) + 32$

exact 3 SFs exact

$= 62.6 + 32 = 94.6\ °F$ *one decimal place*

Slide 63

Learning Check

63

On a cold winter day, the temperature is –15 °C. What is that temperature in °F?

A. 19 °F
B. 59 °F
C. 5 °F

Slide 64

Solution

On a cold winter day, the temperature is –15 °C. What is that temperature in °F?

Step 1 State given and needed quantities.

Given: –15 °C **Need:** T_F

Step 2 **Plan:** $T_C \longrightarrow T_F$

Step 3 Equality/Conversion factor

$T_F = 1.8T_C + 32°$

Step 4 Set up problem.

$T_F = 1.8(-15\ °C) + 32 = -27\ °F + 32 = 5\ °F$

Note: Be sure to use the change sign key on your calculator to enter the minus (–) sign. 1.8 x 15 +/ – = –27

Slide 65

Converting Fahrenheit to Celsius

- T_C is obtained by rearranging the equation for T_F.

$T_F = 1.8T_C + 32$

- Subtract 32 from both sides

$T_F - 32 = 1.8T_C + (32 - 32)$

$T_F - 32 = 1.8T_C$

- Divide by 1.8 = $\frac{T_F - 32}{1.8} = \frac{1.8T_C}{1.8}$

$\frac{T_F - 32}{1.8} = T_C$

Slide 66

Learning Check

The normal body temperature of a chickadee is 105.8 °F. What is that temperature on the Celsius scale?

A. 73.8 °C
B. 58.8 °C
C. 41.0 °C

Slide 67

Solution

67

Step 1 State given and needed quantities.

Given: 105.8 °F **Need:** T_C

Step 2 **Plan:** $T_F \longrightarrow T_C$

Step 3 Equality/Conversion factor

$$T_C = \frac{(T_F - 32)}{1.8}$$

Step 4 Set up problem.

$$= \frac{(105.8 - 32)}{1.8} \quad \text{(32 and 1.8 are } \textit{exact}\text{)}$$

$$= \frac{73.8\ °F}{1.8\ (\textit{exact})} = 41.0\ °C \quad \text{The answer is C.}$$

3SFs 3 SFs

Slide 68

Learning Check

68

A pepperoni pizza is baked at 455 ° F. What temperature is needed on the Celsius scale?

A. 423 °C
B. 235 °C
C. 221 °C

Slide 69

Solution

69

A pepperoni pizza is baked at 455 °F. What temperature is needed on the Celsius scale?

Step 1 State given and needed quantities.

Given: 455 °F **Need:** T_C

Step 2 **Plan:** $T_F \longrightarrow T_C$

Step 3 Equality/Conversion factor

$$T_C = \frac{(T_F - 32)}{1.8}$$

Step 4 Set up problem.

$$\frac{(455° - 32°)}{1.8} = 235\ °C \quad \text{The answer is B.}$$

Slide 70

Kelvin Temperature Scale

70

The **Kelvin temperature**

- scale has 100 units between the freezing and boiling points of water

  100 K = 100 °C   or   1 K = 1 °C

- is obtained by adding 273 to the Celsius temperature

  $T_K = T_C + 273$

- has the lowest possible temperature, absolute zero, at 0 K

  0 K = –273 °C

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Temperatures

71

TABLE 2.6 A Comparison of Temperatures

Example	Fahrenheit (°F)	Celsius (°C)	Kelvin (K)
Sun	9937	5503	5776
A hot oven	450	232	505
A desert	120	49	322
A high fever	104	40	313
Room temperature	70	21	294
Water freezes	32	0	273
A northern winter	−66	−54	219
Helium boils	−452	−269	4
Absolute zero	−459	−273	0

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Learning Check

72

What is normal body temperature of 37 °C in Kelvin?

A. 236 K
B. 310 K
C. 342 K

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Solution

73

What is normal body temperature of 37 °C in Kelvin?

Step 1 State given and needed quantities.

Given: 37 °C **Need:** T_K

Step 2 **Plan:** $T_C \longrightarrow T_K$

Step 3 Equality/Conversion factor

$T_K = T_C + 273$

Step 4 Set up problem.

$T_K = 37\ °C + 273$

$= 310.\ K$ (to ones place) Answer is B.

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Slide 75

Chapter 2 Matter and Energy

75

2.5 Specific Heat

The copper on a pan conducts heat rapidly to the food in the pan.

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Specific Heat

76

Specific heat (SH)

- is different for different substances
- is the amount of heat that raises the temperature of exactly 1 g of a substance by exactly 1 °C
- in the SI system has units of J/g °C
- in the metric system has units of cal/g °C

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Examples of Specific Heats

77

TABLE 2.7 Specific Heats of Some Substances

Substance	J/g °C	cal/g °C
Elements		
Aluminum, Al(*s*)	0.897	0.214
Copper, Cu(*s*)	0.385	0.0920
Gold, Au(*s*)	0.129	0.0308
Iron, Fe(*s*)	0.452	0.108
Silver, Ag(*s*)	0.235	0.0562
Titanium, Ti(*s*)	0.523	0.125
Compounds		
Ammonia, $NH_3(g)$	2.04	0.488
Ethanol, $C_2H_5OH(l)$	2.46	0.588
Sodium chloride, NaCl(*s*)	0.864	0.207
Water, $H_2O(l)$	4.184	1.00
Water, $H_2O(s)$	2.03	0.485

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Learning Check

78

1. When ocean water cools, the surrounding air
   A. cools B. warms C. stays the same

2. Sand in the desert is hot in the day and cool at night. Sand must have a
   A. high specific heat B. low specific heat

Slide 79

Solution

79

1. When ocean water cools, the surrounding air
   B. warms

2. Sand in the desert is hot in the day and cool at night. Sand must have a
   B. low specific heat

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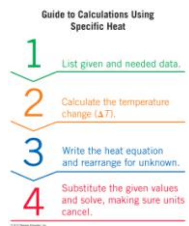
Guide to Solving Specific Heat Problems

80



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Learning Check

81

What is the specific heat if 24.8 g of a metal absorbs 275 J of energy and the temperature rises from 20.2 °C to 24.5 °C?

Slide 82

Solution

82

What is the specific heat if 24.8 g of a metal absorbs 275 J of energy and the temperature rises from 20.2 °C to 24.5 °C?

Step 1 List given and needed data.
Given: 24.8 g of metal, 24.5 °C to 20.2 °C
Need: specific heat, J/g °C

Step 2 Calculate the temperature change.

ΔT = 24.5 °C – 20.2 °C = 4.3 °C

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Solution

83

What is the specific heat if 24.8 g of a metal absorbs 275 J of energy and the temperature rises from 20.2 °C to 24.5 °C?

Step 3 Write the heat equation and rearrange for the unknown.

$$\text{Specific heat (SH)} = \frac{\text{Heat (J)}}{\text{g °C}}$$

Step 4 Substitute the given values and solve.

$$\text{Specific heat (SH)} = \frac{275\ \text{J}}{(24.8\ \text{g})(4.3\ \text{°C})} = 2.6\ \text{J/g °C}$$

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Heat Equation

84

The amount of heat lost or gained by a substance is calculated from the

- mass of substance (g)
- temperature change (ΔT)
- specific heat of the substance (J/g °C)

This is expressed as the **heat equation**.

$$\text{Heat} = \text{g} \times \text{°C} \times \frac{\text{J}}{\text{g °C}} = \text{J}$$

Slide 85

Example of Using Specific Heat

85

A layer of copper on a pan has a mass of 135 g. How much heat, in kilojoules, will raise the temperature of the copper from 26 °C to 328 °C if the specific heat of copper is 0.385 J/g °C?

Slide 86

Using Specific Heat

86

A layer of copper on a pan has a mass of 135 g. How much heat, in kilojoules, will raise the temperature of the copper from 26 °C to 328 °C if the specific heat of copper is 0.385 J/g °C?

Step 1 List given and needed data.

Given: 135 g, 26 °C to 328 °C, *specific heat* = 0.385 J/g °C

Need: joules

Step 2 Calculate the temperature change.

ΔT = 328 °C – 26 °C = 302 °C

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Using Specific Heat

87

A layer of copper on a pan has a mass of 135 g. How much heat, in kilojoules, will raise the temperature of the copper from 26 °C to 328 °C if the specific heat of copper is 0.385 J/g °C?

Step 3 Write the heat equation.

Heat (cal) = g x ΔT x SH(Cu)

Step 4 Substitute the given values and solve.

$$135\ \cancel{g} \times 302\ \cancel{°C} \times \frac{0.385\ \cancel{J}}{\cancel{g}\ \cancel{°C}} \times \frac{1\ kJ}{1000\ \cancel{J}} = 15.7\ kJ$$

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Learning Check

88

How many kJ are needed to raise the temperature of 325 g of water from 15.0 °C to 77.0 °C?

A. 20.4 kJ
B. 77.7 kJ
C. 84.3 kJ

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Solution

89

How many kJ are needed to raise the temperature of 325 g of water from 15.0 °C to 77.0 °C?

Step 1 List given and needed data.
Given: 325 g of water, 15.0 °C to 77.0 °C
SH = 4.184 J/g °C
Need: kilojoules

Step 2 Calculate the temperature change.
ΔT = 77.0 °C – 15.0 °C = 62.0 °C

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Slide 90

Solution

90

How many kJ are needed to raise the temperature of 325 g of water from 15.0 °C to 77.0 °C?

Step 3 Write the heat equation and rearrange for unknown.
$$\text{Heat} = \cancel{\text{g}} \times \cancel{^\circ\text{C}} \times \frac{\text{J}}{\cancel{\text{g}}\,\cancel{^\circ\text{C}}}$$

Step 4 Substitute the given values and solve.
$$\text{Heat} = 325\,\cancel{\text{g}} \times 62.0\,\cancel{^\circ\text{C}} \times \frac{4.184\,\cancel{\text{J}}}{\cancel{\text{g}}\,\cancel{^\circ\text{C}}} \times \frac{1\text{ kJ}}{1000\,\cancel{\text{J}}}$$
= 84.3 kJ The answer is C.

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Chapter 2 Matter and Energy

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2.6

Energy and Nutrition

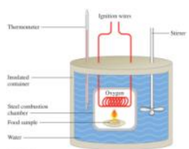
Slide 93

Calorimeters

93

A **calorimeter**

- is used to measure heat transfer
- consists of a steel container filled with oxygen and a measured amount of water
- indicates the heat gained by water, which is the heat lost by a sample during combustion



In a calorimeter, the burning of a food sample increases the temperature of water, which is used to calculate the energy value of the food.

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Energy and Nutrition

94

On food labels, energy is shown as the nutritional Calorie, written with a capital C. In countries other than the United States, energy is shown in kilojoules (kJ).

1 Cal = 1000 calories
1 Cal = 1 kcal

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Caloric Food Values

95

The caloric or energy value for 1 g of a food is given in kilojoules (kJ) or kilocalories (kcal).

TABLE 2.8 Typical Energy (Caloric) Values for the Three Food Types

Food Type	kJ/g	kcal/g
Carbohydrate	17	4
Fat	38	9
Protein	17	4

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Energy Values for Some Foods

96

TABLE 2.9 General Composition and Energy Content of Some Foods

Food	Carbohydrate (g)	Fat (g)	Protein (g)	Energy*
Banana, 1 medium	26	0	1	460 kJ (110 kcal)
Beef, ground, 3 oz	0	14	22	910 kJ (220 kcal)
Carrots, raw, 1 cup	11	0	1	200 kJ (50 kcal)
Chicken, no skin, 3 oz	0	3	20	460 kJ (110 kcal)
Egg, 1 large	0	6	6	330 kJ (80 kcal)
Milk, 4% fat, 1 cup	12	9	9	700 kJ (170 kcal)
Milk, nonfat, 1 cup	12	0	9	360 kJ (90 kcal)
Potato, baked	23	0	3	440 kJ (100 kcal)
Salmon, 3 oz	0	5	16	460 kJ (110 kcal)
Steak, 3 oz	0	27	19	1350 kJ (320 kcal)

*Energy values are rounded off to the tens place.

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Energy Requirements

97

The amount of energy needed by a human each day depends on
- age (see Table 2.10)
- gender
- physical activity (see Table 2.11)

TABLE 2.10 Typical Energy Requirements for Adults

Gender	Age	Moderately active kcal (kJ)	Highly active kcal (kJ)
Female	19–30	2100 (8800)	2400 (10 000)
	31–50	2000 (8400)	2200 (9200)
Male	19–30	2700 (11 300)	3000 (12 600)
	31–50	2500 (10 500)	2900 (12 100)

TABLE 2.11 Energy Expended by a 70.0-kg (154-lb) Adult

Activity	Energy (kcal/h)	Energy (kJ/h)
Sleeping	60	250
Sitting	100	420
Walking	200	840
Swimming	500	2100
Running	750	3100

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Learning Check

98

A cup of whole milk contains 13 g of carbohydrate, 9.0 g of fat, and 9.0 g of protein. How many kilocalories does a cup of milk contain? (Round final answer to the tens place.)

A. 50 kcal
B. 80 kcal
C. 170 kcal

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Solution

99

A cup of whole milk contains 13 g of carbohydrate, 9.0 g of fat, and 9.0 g of protein. How many kilocalories does a cup of milk contain? (Round final answer to the tens place.)

13 g carbohydrates x 4 kcal/g = 52 kcal

9.0 g fat x 9 kcal/g = 81 kcal

9.0 g protein x 4 kcal/g = <u>36 kcal</u>

169 kcal

Rounds off to 170 kcal (tens place)

Answer is C.

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100

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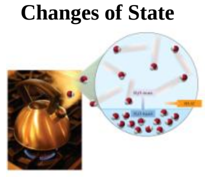
Chapter 2 Matter and Energy

101

2.7
Changes of State



When a gram of steam condenses, 2260 J are released.

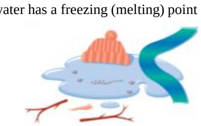
Slide 102

Melting and Freezing

102

A substance

- is **melting** while it changes from a solid to a liquid
- is **freezing** while it changes from a liquid to a solid
- such as water has a freezing (melting) point of 0 °C



A solid requires heat to change to a liquid; a liquid gives off heat to change to a solid.

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Calculations Using Heat of Fusion

103

The **heat of fusion**

- is the amount of heat released when 1 g of liquid freezes (at its freezing point)
- is the amount of heat needed to melt 1 g of solid (at its melting point)
- for water (at 0 °C) is

$\frac{80.\text{ cal}}{1\text{ g } H_2O}$ or $\frac{334\text{ J}}{1\text{ g } H_2O}$

Sublimation and deposition are reversible processes.

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Calculations Using Heat of Fusion

104

Slide 105

Learning Check

105

How many kilojoules are released when 25.0 g of water at 0 °C freezes?

A. 0.335 kJ
B. 0 kJ
C. 8.35 kJ

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Solution

How many kilojoules are released when 25.0 g of water at 0 °C freezes?

Step 1 List the grams of substance and change of state.

Given: 25.0 g of $H_2O(l)$

Need: number of kilojoules to freeze to $H_2O(s)$

Step 2 Write the plan to convert grams to heat.

grams of $H_2O(l) \longrightarrow$ kilojoules (to freeze)

Slide 107

Solution (continued)

Step 3 Write the heat conversion factors and metric factors if needed.

1 g of $H_2O(l \longrightarrow s)$ = 334 J

$\frac{334\ J}{1\ g\ H_2O}$ and $\frac{1\ g\ H_2O}{334\ J}$

1 kJ = 1000 J

$\frac{1\ kJ}{1000\ J}$ and $\frac{1000\ J}{1\ kJ}$

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Solution (continued)

Step 4 Set up the problem with factors.

Heat lost to freeze water at 0 °C

$$25.0\ g\ \cancel{H_2O} \times \frac{334\ \cancel{J}}{1\ g\ \cancel{H_2O}} \times \frac{1\ kJ}{1000\ \cancel{J}} = 8.35\ kJ$$

The answer is C, 8.35 kJ.

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Learning Check

How many joules are needed to melt 15.0 g of ice at 0 °C?

A. 1,200 J
B. 5,010 J
C. 96,000 J

Slide 110

Solution

Step 1 List the grams of substance and change of state.

Given: 15.0 g of $H_2O(s)$

Need: number of joules to melt ice to $H_2O(l)$

Step 2 Write the plan to convert grams to heat.

grams of ice $H_2O(s) \longrightarrow$ joules (to melt)

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Solution (continued)

Step 3 Write the heat conversion factors and metric factor if needed.

1 g of $H_2O(s \longrightarrow l)$ = 334 J

$\frac{334\ J}{g\ of\ H_2O}$ and $\frac{1\ g\ H_2O}{334\ J}$

Step 4 Set up the problem with factors.

Heat to melt ice at 0 °C

$15.0\ \cancel{g\ ice} \times \frac{334\ J}{1\ \cancel{g\ ice}} = 5010\ J$

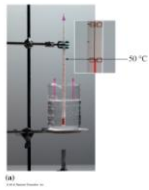
The answer is B, 5010 J.

Slide 112

Evaporation and Condensation

Water

- **evaporates** when molecules on the surface gain sufficient energy to form a gas.
- **condenses** when gas molecules lose energy and form a liquid.



During evaporation, molecules of the liquid are converted to gas at the surface of the liquid.

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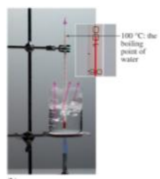
Boiling of Water

When water is **boiling**,

- all the water molecules acquire enough energy to form a gas (vaporize)
- bubbles of water vapor appear throughout the liquid



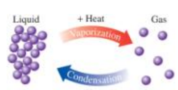
During boiling, molecules of the liquid are converted to gas throughout the liquid as well as at the surface.

Slide 114

Heat of Vaporization

The **heat of vaporization** is the amount of heat

- absorbed to change 1 g of liquid to gas at the boiling point
- released when 1 g of gas changes to liquid at the boiling point



Vaporization and condensation are reversible processes.

Boiling Point of Water = 100 °C

Heat of Vaporization (water)

$\frac{540 \text{ cal}}{1 \text{ g } H_2O}$ or $\frac{2260 \text{ cal}}{1 \text{ g } H_2O}$

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Calculations Using Heat of Vaporization

115

Slide 116

Learning Check

116

How many kilojoules (kJ) are released when 50.0 g of steam from a volcano condenses at 100 °C?

A. 113 kJ

B. 2,260 kJ

C. 113,000 kJ

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Solution

117

How many kilojoules (kJ) are released when 50.0 g of steam from a volcano condenses at 100 °C?

Step 1 List the grams of substance and change of state.

Given: 50.0 g of $H_2O(g)$

Need: number of kilojoules to condense steam to $H_2O(l)$

Step 2 Write the plan to convert grams to heat.

grams of $H_2O(g) \longrightarrow$ kilojoules (to condense)

Slide 118

Solution (continued)

118

Step 3 Write the heat conversion factors and metric factors if needed.

1 g of $H_2O(g \longrightarrow l)$ = 2260 J

$\frac{2260\ J}{1\ g\ H_2O}$ and $\frac{1\ g\ H_2O}{2260\ J}$

1 kJ = 1000 J

$\frac{1\ kJ}{1000\ J}$ and $\frac{1000\ J}{1\ kJ}$

____

Slide 119

Solution

119

Step 4 Set up the problem with factors.

Heat released when $H_2O(g)$ condenses at 100 °C is:

$$50.0\ g\ \cancel{H_2O} \times \frac{2260\ \cancel{J}}{1\ g\ \cancel{H_2O}} \times \frac{1\ kJ}{1000\ \cancel{J}} = 113\ kJ$$

The answer is A.

Slide 120

Sublimation

120

Sublimation

- occurs when a solid changes directly to a gas
- is typical of dry ice, which sublimes at −78 °C
- takes place in frost-free refrigerators
- is used to prepare freeze-dried foods for long-term storage

Heat of Sublimation (water)

$\frac{620.\ cal}{1\ g\ H_2O}$ or $\frac{2590\ cal}{1\ g\ H_2O}$

Dry ice sublimes at −78 °C.

Slide 121

Summary of Changes of State

121

A solid melts to form a liquid and sublimes to form a gas; a liquid boils to form a gas and freezes to form a solid; a gas condenses to form a liquid and undergoes deposition to form a solid.

Slide 122

Heating Curve

122

On a heating curve, diagonal lines indicate changes in temperature for a state, and horizontal lines (plateaus) indicate changes of state.

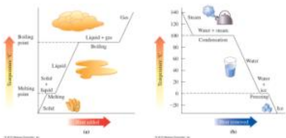

FIGURE 2.10 (a) A heating curve diagrams changes in state as temperature increases. (b) A cooling curve for water diagrams changes in state as temperature decreases.

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Learning Check

123

1. A plateau (horizontal line) on a heating curve represents
   A. a temperature change
   B. a constant temperature
   C. a change of state

2. A sloped line on a heating curve represents
   A. a temperature change
   B. a constant temperature
   C. a change of state

Slide 124

Solution

124

1. A flat line on a heating curve represents
   B. a constant temperature
   C. a change of state

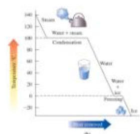
2. A sloped line on a heating curve represents
   A. a temperature change

Slide 125

Cooling Curve

125

A **cooling curve**
- illustrates the changes of state as a gas is cooled
- uses sloped lines to indicate a decrease in temperature
- uses plateaus (flat lines) to indicate a change of state



A cooling curve for water diagrams changes in state as temperature decreases.

On a cooling curve, diagonal lines indicate changes in temperature for a state, and horizontal lines (plateaus) indicate changes of state.

Slide 126

Learning Check

126

Use the cooling curve for water to answer each of the following:

1. Water condenses at a temperature of
   A. 0 °C B. 50 °C C. 100 °C
2. At a temperature of 0 °C, liquid water
   A. freezes B. melts C. changes to a gas
3. At 40 °C, water is a
   A. solid B. liquid C. gas
4. When water freezes, heat is
   A. removed B. added

Slide 127

Solution

127

Use the cooling curve for water to answer each of the following:

1. Water condenses at a temperature of
   C. 100 °C
2. At a temperature of 0 °C, liquid water
   A. freezes
3. At 40 °C, water is a
   B. liquid
4. When water freezes, heat is
   A. removed

Slide 128

Combined Heat Calculations

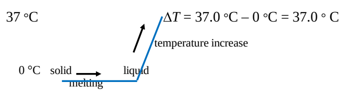
128

To reduce a fever, an infant is packed in 250. g of ice. If the ice (at 0 °C) melts and warms to body temperature (37.0 °C), how many calories are removed from the body?

Step 1 List the grams of substance and change of state.

Given: 250. g of ice $H_2O(s)$; $H_2O(l)$ water at 37.0 °

Need: joules to melt $H_2O(s)$ at 0 °C and warm to 37.0 °C



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Combined Heat Calculations (continued)

129

Step 2 Write the plan to convert grams to heat and desired unit.

$$250.\ \cancel{g\ ice} \times \frac{80.\ cal}{1\ \cancel{g\ ice}} = 20{,}000\ cal\ (2.0 \times 10^3\ cal)$$

Step 3 Calculate the heat to warm the water from 0 °C to 37.0 °C.

$$250.\ \cancel{g} \times 37.0\ \cancel{°C} \times \frac{1.00\ cal}{\cancel{g\ °C}} = 9{,}250\ cal$$

Total: Add Step 2 and Step 3 = 29,000 cal
(rounded off to 1000s place)

Slide 130

Learning Check

130

When a volcano erupts, 175 g of steam at 100 °C is released. How many kilojoules are lost when the steam condenses, then freezes, at 0 °C ?

A. 396 kJ

B. 528 kJ

C. 133 kJ

Slide 131

Solution

131

Step 1 List the grams of substance and change of state.

Given: 175. g of steam $H_2O(g)$; to $H_2O(s)$ at 0 °C

Need: kilojoules to condense $H_2O(g)$ at 100 °C; cool to 0 °C, and freeze at 0 °C

Slide 132

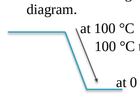
Solution

132

Step 2 Write the plan to convert grams to heat and desired unit.

Total heat = joules to condense steam at 100 °C, cool water to 0 °C, freeze water at 0 °C, cool ice to –5 °C

For several changes, we draw a cooling diagram.



Slide 133

Solution (continued)

133

Step 3 Write the heat conversion factors needed.

1 g of $H_2O(l \longrightarrow s)$ = 334 J

$\frac{334\text{ J}}{1\text{ g } H_2O}$ and $\frac{1\text{ g } H_2O}{334\text{ J}}$

1 g of $H_2O(g \longrightarrow l)$ = 2260 J

$\frac{2260\text{ J}}{1\text{ g } H_2O}$ and $\frac{1\text{ g } H_2O}{2260\text{ J}}$

SH of $H_2O(l)$ = 4.184 J/g °C

$\frac{4.184\text{ J}}{\text{g °C}}$ and $\frac{\text{g °C}}{4.184\text{ J}}$

Slide 134

Solution (continued)

134

Step 4 Set up problem with factors.

Steam condenses at 100 °C

$175\text{ g} \times \frac{2260\text{ J}}{\text{g}} \times \frac{1\text{ kJ}}{1000\text{ J}} = 396\text{ kJ}$

Water cools from 100 °C to 0 °C

$175\text{ g} \times 100\text{ °C} \times \frac{4.184\text{ J}}{\text{g °C}} \times \frac{1\text{ kJ}}{1000\text{ J}} = 73.2\text{ kJ}$

Water freezes to ice at 0 °C:

$175\text{ g} \times \frac{334\text{ J}}{\text{g}} \times \frac{1\text{ kJ}}{1000\text{ J}} = +58.5\text{ kJ}$

528 kJ

Answer is B, 528 kJ.