Ch. 10 - 11

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Problems Ch10 # 3, 5, 11, 17, 21, 24, 25, 29, 33, 37, 39, 43, 47, 59

Problems: CH 11 # 1, 2, 3a, 4, 5, 6, 9, 13, 15, 22, 25, 27, 28, 35

Temperature Scales

- temperature scales

  Celsius

  Fahrenheit

  Kelvin

Celsius Scale

- 0^0C occurs when there is an ice-water mixture
- 0^0C - ice point or freezing point of water
- 100^0C occurs when there is a water-steam mixture
- 100^0C – steam point or boiling point of water

- In Fahrenheit, water freezes at 32 degrees.

- Water boils at 212 degrees.

to convert from Celsius (T_C) to Fahrenheit (T_F) :

$$T_F = (9/5)T_C + 32$$

to convert from Fahrenheit (T_F) to Celsius (T_C) :

$$T_C = (5/9)(T_F – 32)$$

Example: if the temperature is 30^0C

In Fahrenheit the temp. is: $(9/5)30 + 32 = 86^0$F

Kelvin Scale

SI unit of temperature is the kelvin.

- Unlike Celsius and Fahrenheit, the Kelvin scale cannot go negative.
- Absolute zero, or 0 K, is related to having a perfect vacuum. We will see later that is also related a gas of particles having zero kinetic energy.

Kelvin Scale

To convert from Celsius (TC) to Kelvin (T).

$T = T_C + 273.15$

Or from Kelvin (T) to Celsius (T_C)

$T_C = T - 273.15$

In Kelvin:

water freezes at 273.15 and boils at 373.15.

One very useful characteristic is that one degree change in Kelvin is the same as one degree change in Celsius.

Thermal Expansion

- As the temperature of a substance increases, the volume increases.

    Atoms are separated from each other by some distance. As the temperature increases, this separation increases. Thus the whole object expands as temperature increases.

The object expands in all dimensions.

Important to consider when building structures such as bridges. Use thermal expansion joints to compensate for the changes in length.

Thermal Expansion

$$\Delta L = \alpha L_0 \Delta t$$

or

$$L - L_0 = \alpha L_0 (T - T_0)$$

L_0 is the length when temperature is T_0

α= coefficient of linear expansion

Units of α are $1/{}^0C$

See table on page 329

Example of a problem with thermal expansion

- Pour hot water in a cold glass.
  - the inside surface of the glass heats and expands.
  - the outside surface is cooler and expands less.
  - The glass may not withstand the difference in expansion and the glass breaks.

  Pyrex glass has a smaller coefficient of linear expansion. Thus the thermal stresses are reduced.

Volume expansion

As the temperature increases, the volume expands. If the coefficient of linear expansion is the same in all directions, then $\beta = 3\alpha$.

$\Delta V = \beta V_0 \Delta T$

β = coefficient of volume expansion

As global warming happens, the volume of water in the ocean increases. This contributes to rising sea levels.

Side Note about Water

Density of water does not consistently change with the temperature.

As the temperature decreases the volume decreases, UNTIL it drops to 4^0C.

The water expands as it is lowered to the freezing point. Thus ice is less dense that liquid water. Ice floats.

see page 334

Chapter 11

- Heat is the transfer of energy between a system and its environment due to a temperature difference between them.

- Units of heat (has units of energy)
  - calorie
  - Joule

$$1 \text{ cal} = 4.186 \text{ J}$$

Definition of a calorie

Exact definition:

The calorie is defined as the energy necessary to raise the temperature of 1 gram of water from 14.5 to 15.5 degrees Celsius.

Specific Heat

- Specific heat: The amount of energy per unit mass to change the temperature of the substance by 1^0C.

Q – heat transferred

c – specific heat

m – mass

ΔT – change in temperature

$$c = \frac{Q}{m\Delta T}$$

Units for specific heat:

SI unit: $J/(kg^0C)$

We will also use: $cal/(g^0C)$

The calorie unit was fixed so that the specific heat in units of $cal/(g^0C)$ of water would be 1.

Therefore it takes 1 cal to raise a gram of water by 1^0C.

Often we will see the equation written as:

$$Q = mc\Delta T$$

Water

- Water has a relatively large specific heat.
  (see table on 355)
- c_w is almost 5 times as large as c_{Al}
- It takes almost 5 times as much energy to change the temperature of a mass of water than to change an equal mass of aluminum by the same temperature difference.

Calorimetry

Used to measure the unknown specific heat of a material by placing it in thermal equilibrium with a material of known specific heat and measuring the temperature changes.

This works since the heat that leaves one material, goes into the other material.

For example: mixing hot aluminum with colder water. By finding the temperature changes, the specific heat of aluminum can be found.

Example

200 g of iron (c_I = 0.107 cal/(g^{0}C)) is dropped into 100 g of water. The iron is initially at 80 degrees Celsius, while the water starts at 20 degreed Celsius. What will be the final temperature?

Heat leaving iron = Heat entering water

$m_I c_I \Delta T_I = m_w c_w \Delta T_w$

$$m_l c_l \Delta T_l = m_w c_w \Delta T_w$$

$\Delta T_l = 80^0C - T_f$

$\Delta T_w = T_f - 20^0C$

We want to find T_f.

$$(200\,g)(0.107\,\frac{cal}{g^0C})(80^0C - T_f) = (100\,g)(1\frac{cal}{g^0C})(T_f - 20^0C)$$

Do algebra and solve for T_f

$$T_f = 30.6^0C$$

Latent Heat and Phase Change

Many objects can change from one form to another. For example water can be a solid, a liquid, or a gas.

When ice melts, it changes it goes from being in the solid phase to the liquid phase.

Lead can also go from the solid phase to the liquid phase. However this happens at a much higher temperature.

Latent Heat

The energy, Q, needed to change the phase of a pure substance is: $Q = \pm mL$

m = mass

L = latent heat (depends on the nature of the phase change and the substance).

(see table on page 360)

When switching from solid to liquid, $L = L_f$

L_f is the latent heat of fusion.

When switching from liquid to vapor, $L = L_v$

L_v = latent heat of vaporization.

$$Q = \pm mL$$

- The plus or minus sign depends on which way the phase transition is going.
- For water to melt, it must absorb heat.
- When water freezes, it loses heat.

One of your problems involves cold ice transitioning to steam.

You have to break the problem into 5 parts.

1st raise the temperature of the ice to 0^0C.

2nd melt ice

3rd raise temperature of the water to 100^0C

4th change the liquid water to steam(vaporize)

5th heat the steam to the final temperature

By adding the 5 heats required to do these steps you can find the total energy needed to do the complete process.

Types of Energy Transfer

3 ways for thermal energy transfer to occur.

Thermal conduction, when two objects at different temperature are in physical contact with each other, energy will be transferred from the hotter object to the cooler object.

Rate of conduction depends on the thermal conductivity of the materials involved. For example a pot holder has poor thermal conductivity, so it helps keep your hand from being burnt by a hot pot.

Convection

- Convection is the transfer of energy by the movement of a substance.

- Examples:
  - Air in a convection oven circulates, carrying the heat to different locations in the oven.
  - Water cooling an engine by forcing cold water to pass by hot engine parts.
  - Currents in the ocean.

Energy from the Sun

- The Earth is not in contact with the sun, so it can’t be heated by conduction.
- There is no substance such as air in between to circulate the energy from the sun to the Earth, so the Earth is not heated by convection.
- How is the Earth heated?

Radiation

Radiation - objects radiate energy in the form of electromagnetic waves due to the thermal vibrations of their molecules.

Those electromagnetic waves travel through space and deliver the energy.

Another example is the heat you feel when you put your hands near a hot light bulb. Atoms on the bulb are vibrating, which produces the waves that transit the energy.