Chapter 10. Thermal properties of matter

Contents:

New word list:

2.2 Thermal properties and temperature

2.2.1 Thermal expansion of solids, liquids and gases

Core

1 Describe, qualitatively, the thermal expansion of solids, liquids and gases at constant pressure

2 Describe some of the everyday applications and consequences of thermal expansion

Supplement

3 Explain, in terms of the motion and arrangement of particles, the relative order of magnitudes of the expansion of solids, liquids and gases as their temperatures rise

2.2.2 Specific heat capacity

Core

1 Know that a rise in the temperature of an object increases its internal energy

Supplement

2 Describe an increase in temperature of an object in terms of an increase in the average kinetic energies of all of the particles in the object

3 Define specific heat capacity as the energy required per unit mass per unit temperature increase; recall and use the equation

$$c = \frac{\Delta E}{m\Delta\theta}$$

4 Describe experiments to measure the specific heat capacity of a solid and a liquid

2.2.3 Melting, boiling and evaporation

Core

1 Describe melting and boiling in terms of energy input without a change in temperature

2 Know the melting and boiling temperatures for water at standard atmospheric pressure

3 Describe condensation and solidification in terms of particles

4 Describe evaporation in terms of the escape of more energetic particles from the surface of a liquid

5 Know that evaporation causes cooling of a liquid

Supplement

6 Describe the differences between boiling and evaporation

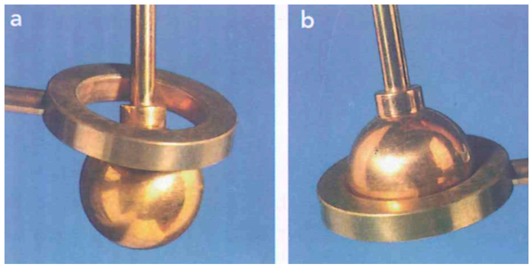
7 Describe how temperature, surface area and air movement over a surface affect evaporation

8 Explain the cooling of an object in contact with an evaporating liquid

10.1 Thermal expansion

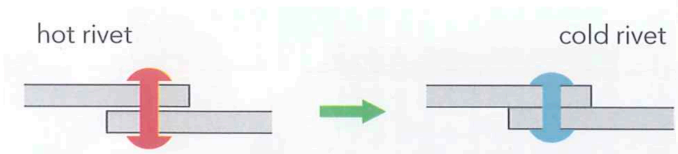
cause：

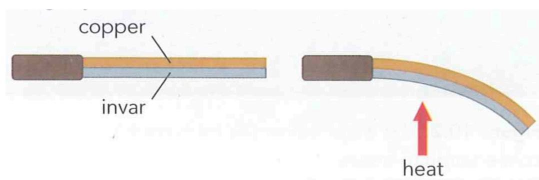
10.1.1 The thermal expansion of solids



Applications:

1. Rivet
2. Metal lid
3. Steel tyre
4. Bimetallic strip





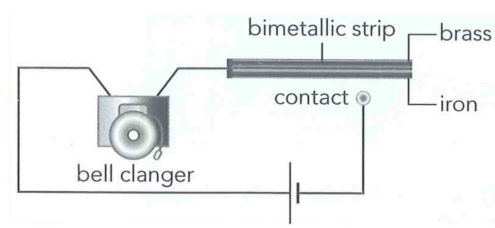
Consequence:

1. Metal bridges
2. Concrete road

Exercise 10.1

The diagram shows the circuit for a fire alarm using a bimetallic strip.

a. Brass expands more than iron. Which metal should be at the top of the strip?
b. Describe what happens as the temperature raises in case of a fire?

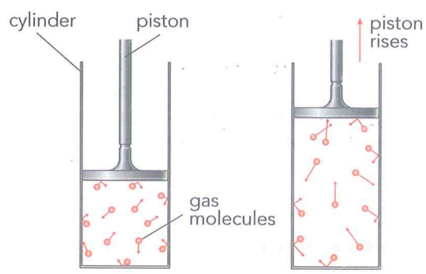


a. Brass should be on the top
b. The bar will bend downwards, the completing the circuit so that the bell rings

10.1.2 The thermal expansion of liquids

Applications:

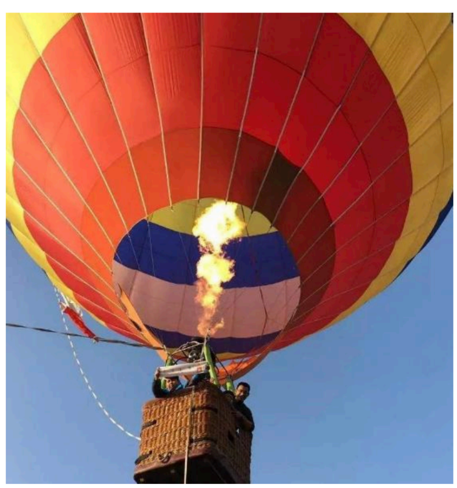
10.1.3 The thermal expansion of gases



Heat the gas

Gases expand -> density decreases -> hot air rises

Application:



10.1.4 Comparison of expansion in solids, liquids and gases

When heated, particles don't get any bigger but have more energy =>

States	Thermal expansion	Explanation
Solid		
Liquid		
Gas		

10.2 Specific heat capacity

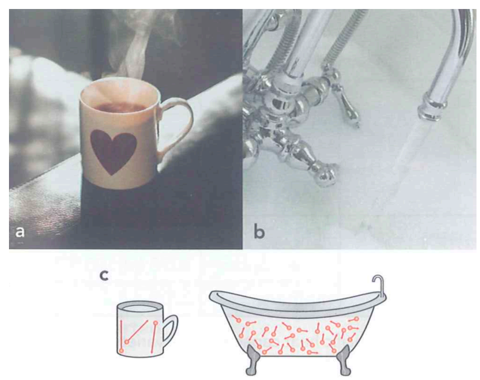
10.2.1 Energy and temperature

Relation: it takes energy to raise temperature

Compare the heat needed to raise temperature in following two scenarios:

A. Raise a bottle of water from 10$^\circ C$ to 20$^\circ C$, or from 10$^\circ C$ to 100$^\circ C$;

B. Raise a bottle of water from 10$^\circ C$ to 20$^\circ C$, or a tank of water from 10$^\circ C$ to 20$^\circ C$;



So, the amount of energy need to heat water depends on:

10.2.2 Specific heat capacity

Specific heat capacity of a substance:

Equation:

Equation in word:

Unit: J/(kg $\cdot ^\circ C$)

Delta: change in

Example: it takes 4200 J to raise the temperature of 1kg water by 1$^\circ C$, the specific capacity of water is (4200 J/(kg $\cdot ^\circ C$)

Exercise 10.3:

A kettle heats 1.5kg of water. How much energy is needed to raise the temperature of water from 20$^{\circ}C$ to 60$^{\circ}C$? from 20$^{\circ}C$ to 90$^{\circ}C$?

Different material has different specific heat capacities

: different material require different amount of energy to raise the same amount of substance by same amount of temperature

Type of material	Material	Specific heat capacity / J/(kg °C)
metals	steel	420
	aluminium	910
	copper	385
	gold	300
	lead	130
non-metals	glass	670
	nylon	1700
	polythene	2300
	ice	2100
liquids	water	4200
	sea water	3900
	ethanol	2500
	olive oil	1970
gases	air	1000
	water vapour	2020 (at 100 °C)
	methane	2200

Energy transfers to make solid molecules vibrate more and gas molecules move faster.

10.2.3 The specific heat capacity of water

water: high specific heat capacity

So,

Can you think of any phenomena relating to this fact?

Exercise 10.4

A cook heats 500g of olive oil in a steel pan which has a mass of 300g, the oil needs to be heated form 20˚C to 190˚C. Using the data from previous table to calculate the thermal energy needed:

To heat the pan

To heat the oil

In total

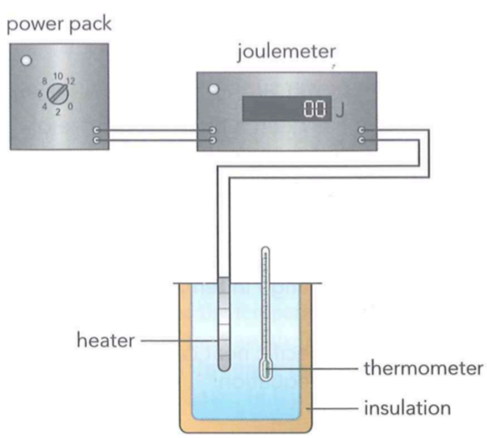
Exercise 10.5

The electric kettle has a power rating of 2000 W. It takes 90s to heat 500g water from 20˚C to boiling. Use this information to calculate an approximate value for specific heat capacity of water.

Compare your answer to the specific heat capacity of water given in the table before.

Comment on why it is different

10.2.4 Measuring the specific heat capacity of water:



1. Put 0.25 kg of water into the beaker.
2. Set up the experiment as shown in Figure 10.15.
3. Measure and record the initial temperature (θ_1) of the block.
4. Turn on the power supply and leave until the temperature changes by about 50 °C.
5. Turn off the power supply. Record the final temperature (θ_2).
6. Calculate the change in temperature using $\Delta\theta = \theta_2 - \theta_1$.
7. Record the joulemeter reading.
8. Calculate the specific heat capacity of the metal using the equation:

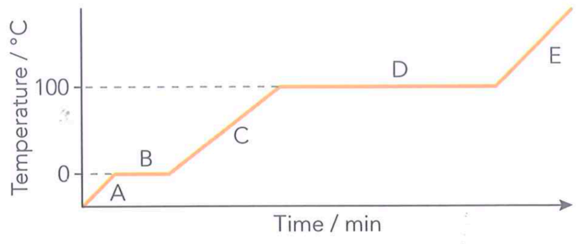
$$c = \frac{\Delta E}{m\Delta\theta}$$

Compare your answers with the value of specific heat capacity given in table before, are they higher or lower? explain the difference.

10.3 Changing state

10.3.1 Temperature change during state changing

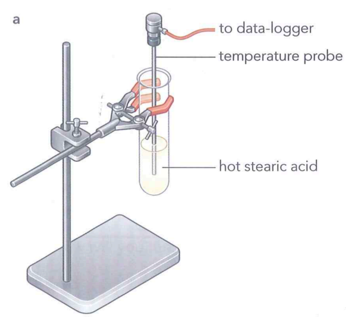
Keep heating ice:



During change of states,
from liquid to gas (i.e. water -> steam)
the temperature ( ). Energy is taken in and used to ( ).
from solid to liquid (i.e. ice -> water)
the temperature ( ). Energy is taken in and used to (
).
When changes are reversed, energy ( ).

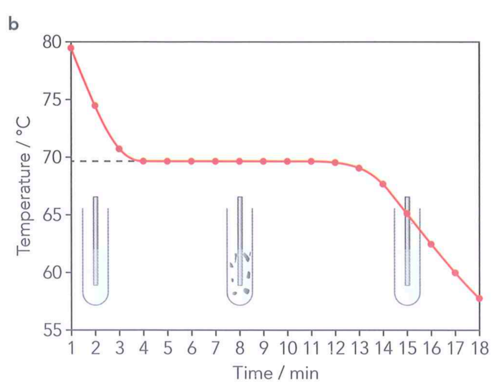
10.3.2 Investigating a change of state

Settings:



Stearic acid: waxy substance,
warm: clear, colorless liquid

Results:



Hotter than surrounding: energy transfer from wax;

At first, liquid wax cools down, its temperature drops gradually;
As the temperature drops, the temperature difference btw wax and surroundings gets smaller, it cools more slowly, the graph slightly curved;

Clear liquid; mixture of clear liquid and white solid; white solid

More about melting point & boiling point
Depends on temperature

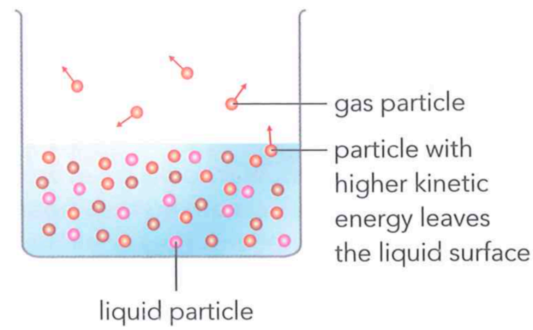
Does air has a fixed boiling point?
A pure substance: fixed boiling/melting point
A mixture of substances: over a range of temperatures

10.3.3 Evaporation
Liquid -> gas (water => water vapor)

After it rains, the puddles dry up even though the temperature is much lower than 100˚C. Why?

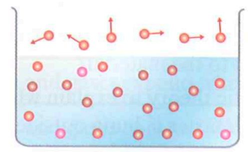
But on a hot day the puddles disappear quickly than on a cold

How to explain evaporation using kinetic model of matter?

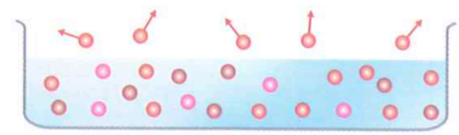


Comparing evaporation and boiling

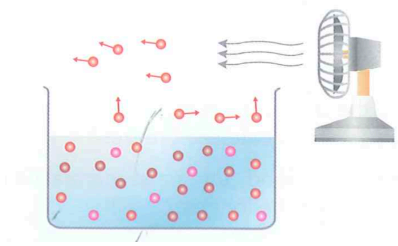
Speeding up evaporation



1.
The particles on average have more kinetic energy;
More of particles will have enough energy to escape;
Liquid evaporates more quickly



2.
More of the particles are close to the surface,
They can escape more easily.
Liquid evaporates more quickly



3.
When particles escape from the water, they are blown away so that they cannot fall back into water
Helps the liquid evaporate quickly

Exercise 10.6

Explain in terms of movement and position particles what happens to an ice cube as it is heated and melts.

Exercise 10.7

Tungsten melts at a much higher temperature than iron. What can you say about the forces between the tungsten atoms, compared to the forces between the iron atoms

Exercise 10.8

A solid is heated but its temperature does not rise.
What is happening to the solid: it is melting
What happens to the energy that is being supplied to the material:
Energy required to break bonds between particles(it increases their potential energy)

Exercise 10.9

Explain how covering a bottle of milk with a damp cloth will help to cool the milk.

The water from the damp cloth will evaporate and will take energy away from milk.