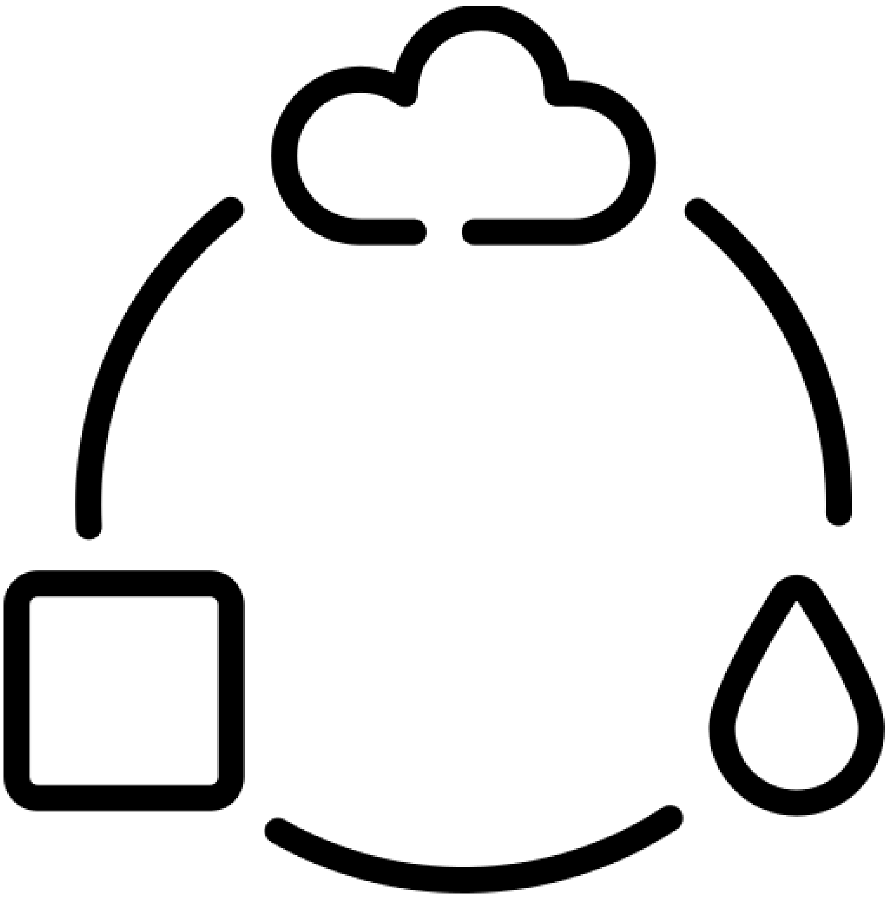
Energy of



Moving Particles

Name	______________________________
Class	______________________________
Teacher	______________________________

L1 Particle model

A substance is solid at temperatures below its **melting point**.

A substance is liquid at temperatures between its melting and boiling point.

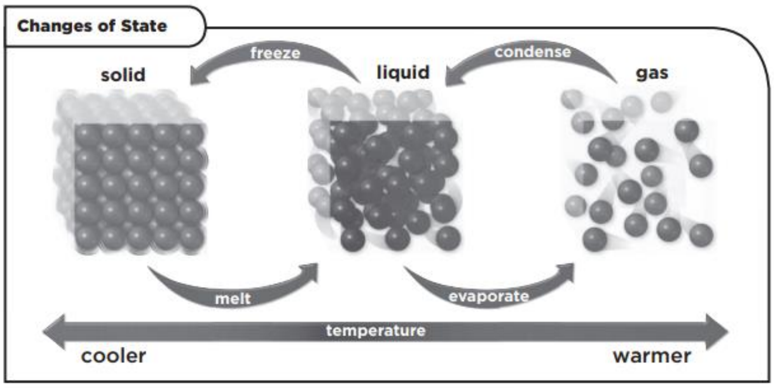
A substance is gas at temperatures above its **boiling point**.

Mini-task:

1. Which metal has the highest melting point?
2. Which metal has the lowest melting point?
3. Which metal is a liquid at room temperature (25°C)?
4. Which 2 metals would be liquid at 100°C?
5. What state would Iron be at a temperature of 900°C?

Metal	Melting point in °C
Gold	1064
Mercury	-37
Sodium	98
Iron	1540

The boiling point of water is **100°C**, while the melting point is **0°C**.



The state changes are shown in the diagram above.

Solid → Liquid **Melting**

Liquid → Gas **Evaporation**

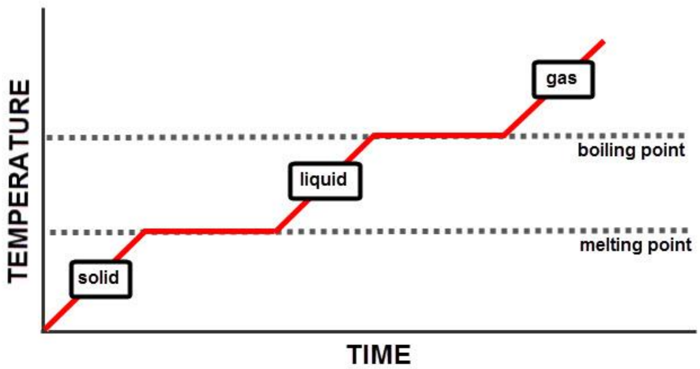
Gas → Liquid **Condensation**

Liquid → Solid **Freezing**

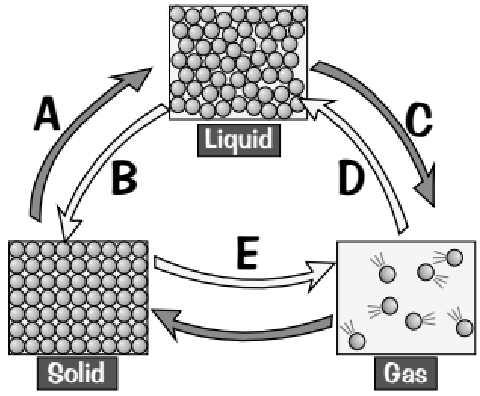
Solid → Gas **Sublimation**

Gas → Solid **Deposition**

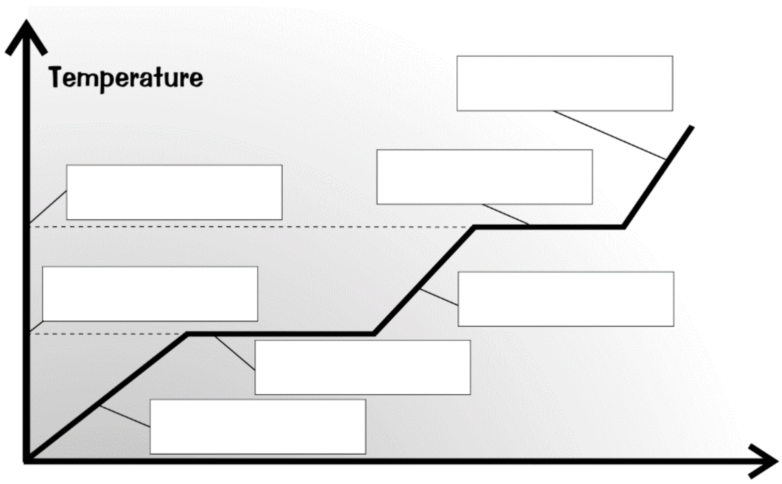
Before a state change, energy goes into **raising** the temperature of the material.



While the state is changing, the temperature of the material stays **constant**. This is because energy goes into breaking the bonds (forces between particles).



1. A, B, C, D and E represent changes from one state to another. Name each of these changes.
2. What is happening to the particles in the substance when change C happens?
3. These sentences are wrong. Rewrite them so that they are correct.
   a) When the state of a substance changes, the energy of the particles doesn't change.
   b) A change of state involves a change in mass.
   c) Condensing is the opposite of melting.

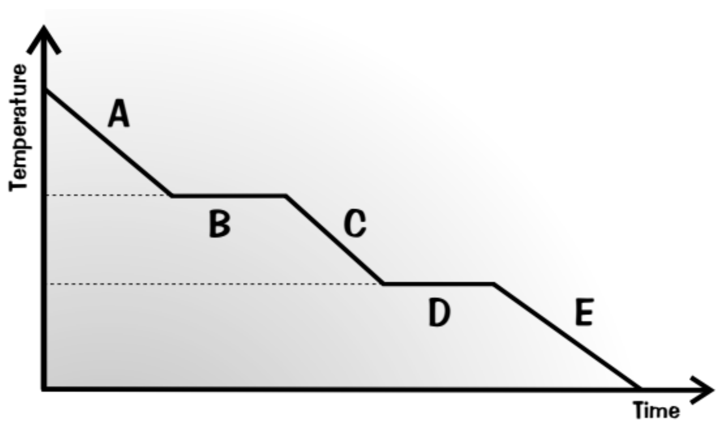


4. Which state must be supplied with the most energy to turn it into a gas? Explain your answer.
5. When energy is supplied to a solid, what happens to the particles within it. Answer in terms of the energies of the particles and how they are moving?
6. Fill in the blanks on the heating curve by using the words given in the word box.

boiling point	**melting point**	**solid**	**melting**
liquid	**boiling**	**gas**	

A scientist measured the temperature of water as it was cooled from 150°C to -20°C. She used her results to make the graph.

7. What state is the water in at points A, C and E?
8. Name the processes that are happening at points B and D.
9. Explain why the graph is flat at points B and D. Use the words forces, energy and particles in your answer.
10. Describe what happens to the arrangement of particles as it goes through state change D.
11. Solid, liquid and gas are three different states of matter.



(a) Describe the difference between the solid and gas states, in terms of the arrangement and movement of their particles.

L2 Energy stores and transfers

Understanding how energy is stored and transferred is crucial because it plays a crucial role in our everyday lives and in various scientific phenomena.

<u>Energy Stores</u>

Kinetic Energy Store: Imagine a moving car. The energy associated with its motion is stored in its kinetic energy store. The faster it moves, the more kinetic energy it has.

Gravitational Potential Energy Store: When you lift an object against gravity, like lifting a book from the ground to a shelf, you're adding energy to its gravitational potential energy store.

Elastic Potential Energy Store: Stretching a rubber band or compressing a spring stores energy in their elastic potential energy stores. When released, this energy is transferred.

Chemical Energy Store: Food, fuels, and batteries all contain chemical energy. When we eat, burn fuel, or use batteries, we release this energy through chemical reactions.

Thermal Energy Store: Think about a hot cup of tea. The energy responsible for its temperature is stored in its thermal energy store. The hotter it is, the more thermal energy it contains.

<u>Energy Transfers</u>

Mechanical Energy Transfer: When you ride a bicycle, your muscular energy is transferred to the bike's kinetic energy store, making it move.

Electrical Energy Transfer: Plug in your smartphone to charge it, and electrical energy from the socket is transferred to your phone's chemical energy store in the battery.

Thermal Energy Transfer: Cooking food on a stove transfers thermal energy from the stove's electrical energy store to the food's thermal energy store.

Radiation Energy Transfer: The Sun transfers energy to Earth through radiation. Sunlight contains radiant energy, which warms our planet.

Sound Energy Transfer: When you play music on a speaker, electrical energy is converted to sound energy, creating vibrations in the air that reach your ears.

Nuclear Energy Transfer: In nuclear reactors, the process of nuclear fission transfers energy from the nucleus of atoms to thermal energy, which can be used to generate electricity.

<u>Conservation of Energy</u>

Energy cannot be created or destroyed; it can only be transferred or converted from one form to another. This is known as the law of conservation of energy.

Independent Practice

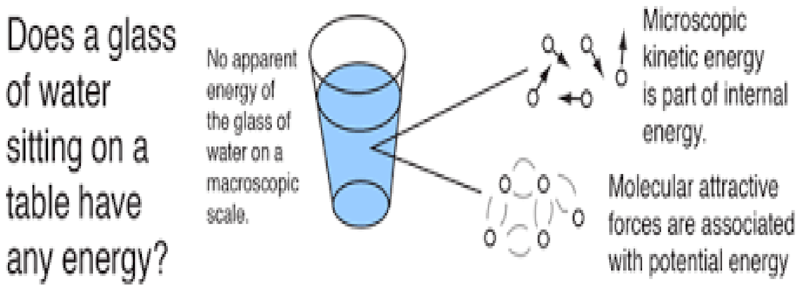
1. What is the kinetic energy store, and can you give an example?
2. Explain how gravitational potential energy is related to an object's height.
3. Give an example of a situation where energy is stored in an elastic potential energy store.
4. Describe the energy transformations when you eat food.
5. How does thermal energy store relate to the temperature of an object?
6. Give an example of a mechanical energy transfer.
7. What happens during electrical energy transfer when charging a smartphone?
8. How is thermal energy transferred when cooking food on a stove?
9. Explain radiation energy transfer from the Sun to Earth.
10. Describe the energy transformation involved in playing music on a speaker.
11. In nuclear reactors, what energy transfer process occurs?
12. What is the law of conservation of energy, and why is it important?
13. How do you calculate efficiency, and why is it useful to know?
14. If a machine is 75% efficient, how much useful energy is produced when it consumes 1,000 J of energy?

L3 Internal energy

Internal energy is a fundamental concept that plays a crucial role in understanding various natural processes. By the end of this explanation, you'll have a solid grasp of what internal energy is and how it influences the world around us.

What is Internal Energy?

Internal energy refers to the total energy contained within a system of particles. These particles could be atoms or molecules in gases, liquids, or solids. Essentially, it's the sum of all the kinetic and potential energy stored within these particles. Think of it as the energy "inside" a substance that causes it to be hot or cold, and it's measured in joules (J).



Factors Influencing Internal Energy

Temperature: Temperature is a measure of the average kinetic energy of particles in a substance. Higher temperature means more internal energy, and vice versa.

Mass: A larger amount of substance contains more internal energy because there are more particles.

Phase: The phase of matter also affects internal energy. For example, a liquid generally has more internal energy than a solid because the particles in a liquid have more freedom to move.

Specific Heat Capacity: Different substances have different abilities to store internal energy. This property is known as specific heat capacity. Water, for instance, has a high specific heat capacity, meaning it can absorb a lot of energy without a significant temperature change.

Changes in Internal Energy

Internal energy can change in several ways:

Heating: Adding heat to a substance increases its internal energy, which can raise its temperature.

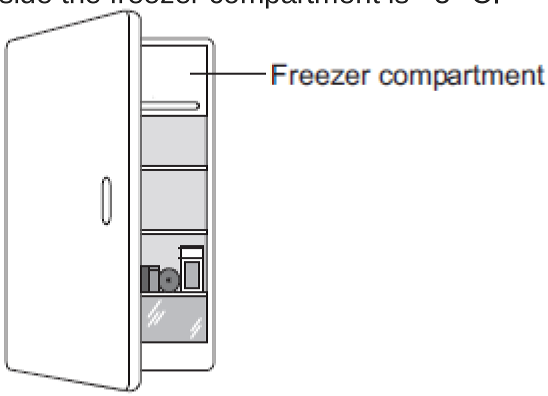
Cooling: Removing heat from a substance decreases its internal energy, which can lower its temperature.

Change of Phase: When a substance changes from one phase to another (e.g., from solid to liquid), there is a change in internal energy.

Chemical Reactions: Chemical reactions can either release or absorb energy, resulting in changes in internal energy.

Independent Practice

1. Define internal energy in your own words.
2. What units are used to measure internal energy?
3. How does temperature relate to internal energy?
4. Explain the effect of mass on internal energy.
5. Describe how the phase of matter influences internal energy.
6. What is specific heat capacity, and why is it important when discussing internal energy?
7. What happens to internal energy when you heat a substance?
8. How does internal energy change when a substance cools down?
9. Give an example of a change in internal energy due to a change in phase.
10. How do chemical reactions affect internal energy?
11. Can you think of a real-life example where understanding internal energy is crucial?
12. Explain why a pot of water takes longer to boil than a pot of oil, considering their different specific heat capacities.
13. What is the internal energy of a substance that is at absolute zero temperature?
14. How does the internal energy of a gas change when it expands against a piston?
15. Imagine you have two identical containers of water, one at 20°C and the other at 80°C. Which one has higher internal energy, and why?
16. The figure below shows a fridge with a freezer compartment.
The temperature of the air inside the freezer compartment is –5 °C.



17.

Use all of the following phrases or words to explain what happens when we open the freezer door

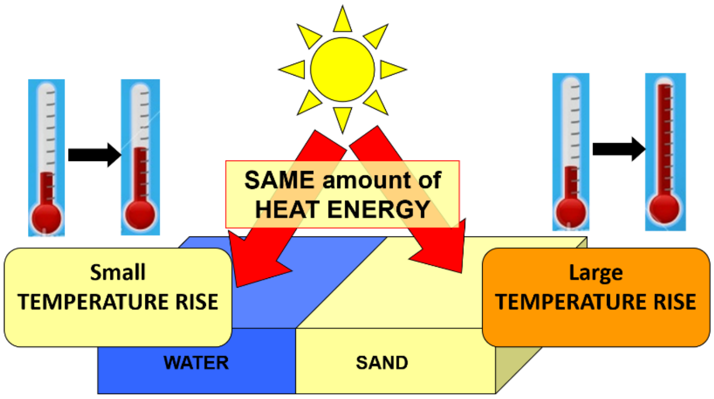
Air particles, reduces, space, internal energy, kinetic energy, potential energy

When the air near the freezer compartment is cooled….

L4 Specific heat capacity

Putting the same amount of heat energy into some materials gives a bigger temperature rise than in other materials. This is due to **specific heat capacity**.

An example of this is on a sandy beach on a sunny day. The water in the sea will be relatively cool, but the sand will be much hotter. This is because water has a higher specific heat capacity than air, and therefore takes more energy to increase in temperature.



The specific heat capacity (c) is the amount of energy needed to increase the temperature of 1 kg of a substance by 1 °C.

A material with a higher specific heat capacity takes more energy to heat up 1 kg by 1 °C than a material with a lower specific heat capacity.

Energy can be calculated using the following:

$$\Delta E = m \times c \times \Delta\theta$$

Where:

- **ΔE** = change in thermal energy (J)
- **m** = mass (kg)
- **c** = specific heat capacity (J/kg°C)
- **Δθ** = change in temperature (°C)

BASIC

1. Calculate the **energy ΔE** (in **J**) for each of the following:

   a. m = 10 kg and Δθ = 4 °C (for **water**)
   b. m = 15.5 kg and Δθ = 0.5 °C (for **aluminium**)
   c. m = 0.5 kg and Δθ = 20 °C (for **copper**)
   d. m = 2 kg and Δθ = 60 °C (for **oil**)
   e. m = 800 kg and Δθ = 7.5 °C (for **concrete**)
   f. m = 1.2 kg and Δθ = 0.5 °C (for **air**)
   g. m = 2 kg and Δθ = 8 °C (for **lead**)
   h. m = 1500 kg and Δθ = 0.2 °C (for **iron**)

Material	Specific heat capacity ($Jkg^{-1}K^{-1}$)
Air	100
Lead	130
Copper	390
Iron	450
Oil	540
Aluminium	899
Concrete	900
Water	4200

MEDIUM (have to use rearranged equations)

2. Calculate the **mass m** (in **kg**) for each of the following.
   a. ΔE = 1 000 J and Δθ = 2.5 °C (for **oil**)
   b. ΔE = 2 500 J and Δθ = 0.2 °C (for **lead**)
   c. ΔE = 200 J and Δθ = 1 °C (for **concrete**)
   d. ΔE = 5,000,000 J and Δθ = 15 °C (for **water**)

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

3. Calculate the **temperature change Δθ** (in **°C**) for each of the following:
   a. ΔE = 3 000 J and m = 20 kg (for **air**)
   b. ΔE = 6 600 J and m = 0.3 kg (for **iron**)
   c. ΔE = 700 J and m = 0.1 kg (for **aluminium**)
   d. ΔE = 20 J and m = 0.02 kg (for **copper**)

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

HARD (have to convert units)

4. Calculate the **energy E** (in **J**) for each of the following:

   a. m = 10 g and Δθ = 5 °C (for **water**) *You need to change **g** into **kg***
      m = 10 g = _______ kg
      *Now you can calculate the energy in **J**.*
      E = _______ J
   b. m = 12.2 g and Δθ = 10.1 °C (for **concrete**)

   c. m = 300.3 g and Δθ = 0.8 °C (for **copper**)

to go **from g to kg** → **÷ 1 000**

5. Calculate the **mass m** (in **kg**) for each of the following:
   a. E = 10 kJ and Δθ = 20 °C (for **aluminium**) *You need to change **kJ** into **J***
      E = 10 kJ = _______ J
      *Now you can calculate the mass in **kg**.*
      m = _______ kg
   b. E = 0.6 kJ and Δθ = 2.2 °C (for **lead**)
   c. E = 0.05 kJ and Δθ = 50 °C (for **oil**)

to go **from kJ to J** → **× 1 000**

L5 Specific Latent Heat

Heating a substance changes the internal energy (KE and GPE of the particles) of the substance by **increasing the energy of its particles**. As a result:

- The **temperature** of the substance **increases**
  OR
- The substance changes its state (i.e. it **melts** or it **boils**)

Before 1 kg of ice melts into 1 kg of water, it must be given 340 000 J of energy.

This is called latent heat ('hidden heat') because it does not increase the temperature - it is still at 0°C.

The **specific latent heat L** of a substance is the **amount of energy required to change the state of 1 kg of the substance with no change in temperature**.

We can calculate this energy by using the equation:

E = m x L

Where:

- **E** is energy in **J**
- **m** is mass in **kg**
- **L** is specific latent heat in **J/kg**

When a substance goes **from solid to liquid** (or vice versa) we talk about **specific latent heat of fusion** L_F.

When a substance goes **from liquid to gas** (or vice versa) we talk about **specific latent heat of vaporisation** L_V.

SPECIFIC LATENT HEAT CALCULATIONS

BASIC

1. Calculate the **energy E** (in **J**) for each of the following:
   a. m = 10 kg and L = 25 000 J/kg
   b. m = 15.5 kg and L = 15 000 J/kg

2. Calculate the **mass m** (in **kg**) for each of the following:
   a. E = 50 500 J and L = 2 200 J/kg
   b. E = 24 300 J and L = 1 300 J/kg

3. Calculate the **specific latent heat L** (in **J/kg**) for each of the following:
   a. E = 3 500 J and m = 20 kg
   b. E = 6 800 J and m = 0.3 kg

MEDIUM

to go **from g to kg —> ÷ 1 000**

1. Calculate the **energy E** (in **J**) for each of the following:
   a. m = 20 g and L = 55 000 J/kg
      *You need to change **g** into **kg***
      m = 20 g = ______ kg
      *Now you can calculate the energy in **J***
      E = ______ J
   b. m = 14.4 g and L = 88 000 J/kg
   c. m = 300.3 g and L = 30 000 J/kg

to go **from kJ to J —> x 1 000**
to go **from MJ to J —> x 1 000 000**
to go **from GJ to J —> x 1 000 000 000**

2. Calculate the **mass m** (in **kg**) for each of the following:
   a. E = 60 kJ and L = 22 000 J/kg
      *You need to change **kJ** into **J***
      E = 60 kJ = ______ J
      *Now you can calculate the mass in **kg***
      m = ______ kg
   b. E = 0.6 MJ and L = 6 000 J/kg
   c. E = 0.05 GJ and L = 21 000 J/kg

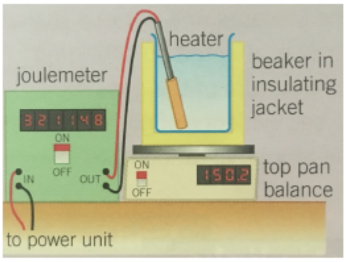


Figure 1

HARD

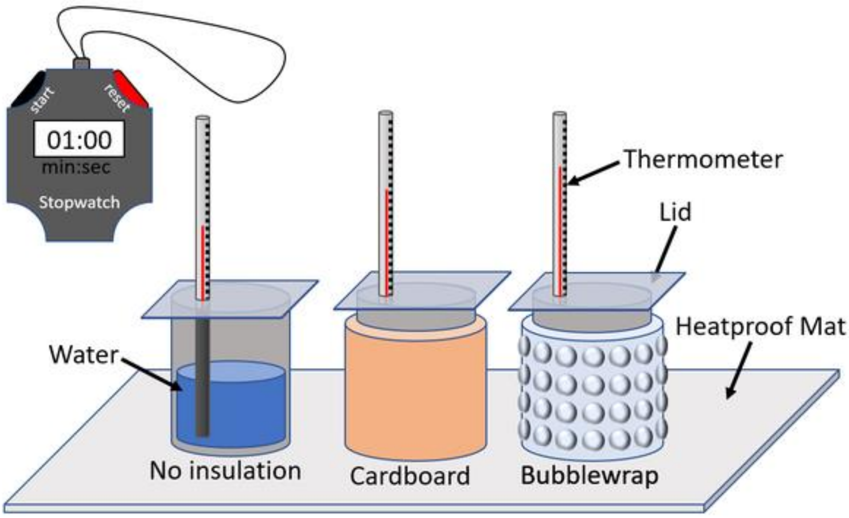
1. Calculate the energy transferred to the surroundings as 0.40 kg of stearic acid change state from solid to liquid. The specific latent heat of fusion of stearic acid is 199 000 J/kg.
2. While a kettle boils, 0.018 kg of water changes to steam. Calculate the amount of energy required for this change. The specific latent heat of vaporisation of water is 2.3 MJ/kg.
3. The apparatus shown in **Figure 1** is used to measure the specific latent heat of vaporisation of water. The balance reading decreased from 0.152 kg to 0.144 kg in the time taken to supply 18 400 J of energy to the boiling water. Use the data to calculate the specific latent heat of vaporisation of water.
4. If the specific latent heat of fusion of water is 340 000 J/kg and the specific latent heat of vaporisation of water is 2.3 MJ/kg, calculate:
   a. the energy needed to melt 2 kg of ice at 0 °C
   b. the energy needed to melt 500 g of ice at 0 °C
   c. the energy needed to boil 3 kg of water at 100 °C
   d. the energy needed to boil 100 g of water at 100 °C

L6 Thermal insulation RPA – Triple only

Thermal Insulation

Thermal insulation is all about how well a material can slow down the transfer of heat. When it's cold outside, we use insulation to keep our homes warm, and when it's hot, we use it to keep our buildings cool. Understanding how to measure and compare the insulating properties of different materials is crucial in various industries, from construction to energy efficiency.

Required Practical Activity



The required practical activity for thermal insulation involves testing different materials to see which one is the best insulator. This experiment is designed to help you understand the concept of control variables and identify potential sources of error.

Variables

Independent Variable: This is the variable you change deliberately. In this experiment, it's the type of material you use (e.g., cotton, foam, aluminum foil).

Dependent Variable: This is what you measure as a result of changing the independent variable. Here, it's the rate of heat loss or gain.

Control Variables: These are the factors you keep constant to ensure a fair test. They include:

Temperature: Make sure the initial temperature of the materials and surroundings is the same.

Surface Area: Keep the surface area of the materials constant to make comparisons valid.

Time: Measure the rate of heat transfer at the same time intervals for each material.

Thickness: Maintain a consistent thickness of the materials you're testing.

Sources of Error

Even with meticulous planning, experiments can have sources of error that affect the reliability of your results. Identifying these sources of error is a crucial part of the scientific process.

Measurement Errors: Using inaccurate measuring equipment can introduce errors into your data. Ensure you use calibrated thermometers and rulers.

Heat Loss to the Environment: Heat can escape from your materials to the surroundings. Minimize this by insulating your setup and using a cover for the materials.

Human Error: Errors in timing or recording data can happen. Take care to be precise in your observations and measurements.

Variations in Thickness: Even if you aim for uniform thickness, variations might exist within the materials.

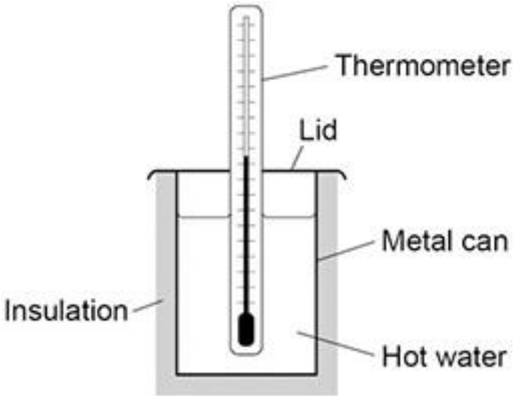
Radiation: Heat can be lost or gained through radiation, particularly in materials with reflective surfaces like aluminum foil. Be aware of this potential error source.

Conduction: Ensure that the materials don't have direct contact with each other, as this can lead to conduction of heat.

Air Gaps: When layering materials, air gaps can form between them, affecting their insulating properties.

Independent practice

1. What is the main purpose of thermal insulation?
2. Describe the independent variable in this experiment.
3. Explain the dependent variable.
4. List three control variables in the thermal insulation experiment.
5. Why is it essential to keep the initial temperature of materials and surroundings the same?
6. How can you minimize heat loss to the environment during the experiment?
7. What precautions should you take to minimize measurement errors?
8. What is the potential source of error related to radiation in this experiment?
9. How can you ensure that materials don't have direct contact with each other?
10. Why should you be cautious about air gaps when layering materials?
11. Why is it crucial to measure the rate of heat transfer at the same time intervals for each material?
12. Why is the thickness of the materials a control variable in this experiment?
13. What are the real-world applications of understanding thermal insulation?
14. Can you think of any other potential sources of error that might affect this experiment?
15. A student investigated the insulating properties of different materials.
16. **Figure 1** shows some of the equipment used by the student.
17. **Figure 1**



This is the method used:

1. Wrap insulating material around the can.
2. Put a fixed volume of boiling water in the can.
3. Place the lid on the top of the can.
4. Measure the time taken for the temperature of the water to decrease by a fixed amount.
5. Repeat steps 1 – 4 using the same thickness of different insulating materials.

(a) Identify the independent variable and the dependent variable in this investigation.

Independent variable ____

Dependent variable ____

(2)

The student used two different types of thermometer to measure the temperature changes.

Figure 2 shows a reading on each thermometer.

Figure 2

(b) What is the resolution of thermometer **B**?

Resolution = ________________°C

(1)

(c) Thermometer **A** is more likely to be misread.

Give **one** reason why.

____

____

____

18. (1)