The Structure of Atom 2

Kinetic Theory of Matter

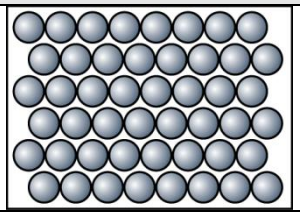
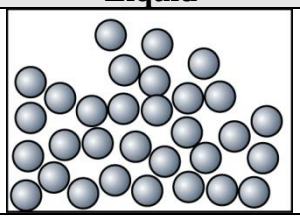
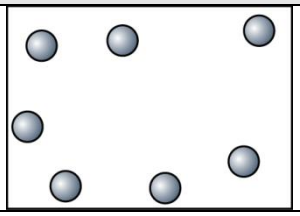
1. The characteristics of matter can be described using the kinetic theory of matter.

The kinetic theory of matter explains the state of matter in solid, liquid and gaseous states based on the following assumptions:

a) The gas consists of very small particles, each of which has a mass.
b) These molecules are in constant, random **motion**. The rapidly moving particles constantly collide with each other and with the walls of the container.
c) There are forces of attraction between particles of matter. These attraction forces will increase as the distance between the particles becomes closer.
d) The average kinetic energy of the gas particles depends only on the temperature of the system. The higher the temperature, the higher the kinetic energy of the particles.

State of Matter

Matter exists in 3 states of matter, namely, solid state, liquid state and gaseous state.
Characteristics of Matter in Solid, Liquid and Gaseous State

Characteristics	Solid	Liquid	Gas
			
Arrangement of Particles	• Particles are arranged in orderly manner and close to one another.	• Particles are not arranged in order. • The space between particles is moderately large.	• The particles are very far apart and randomly arrange.
Movement of Particles	Particles vibrate at fixed positions.	Particles move randomly and slowly and sometimes will collide against each other.	The particles move randomly in all directions at great speed.
Force of Attraction between particles	very strong	Strong but weaker than in the solid state.	very weak
Ability to be compressed	Very difficult to be compressed because the particles are packed closely.	Not easily compressed because the particles are packed quite closely.	Easily compressed because the particles are very far apart.
Volume	Fixed	Fixed	Follows the container
Heat Energy content	Lowest Energy Content	Moderate energy content.	Highest energy content
Shape	Fixed	Follows the container	Fills the whole container

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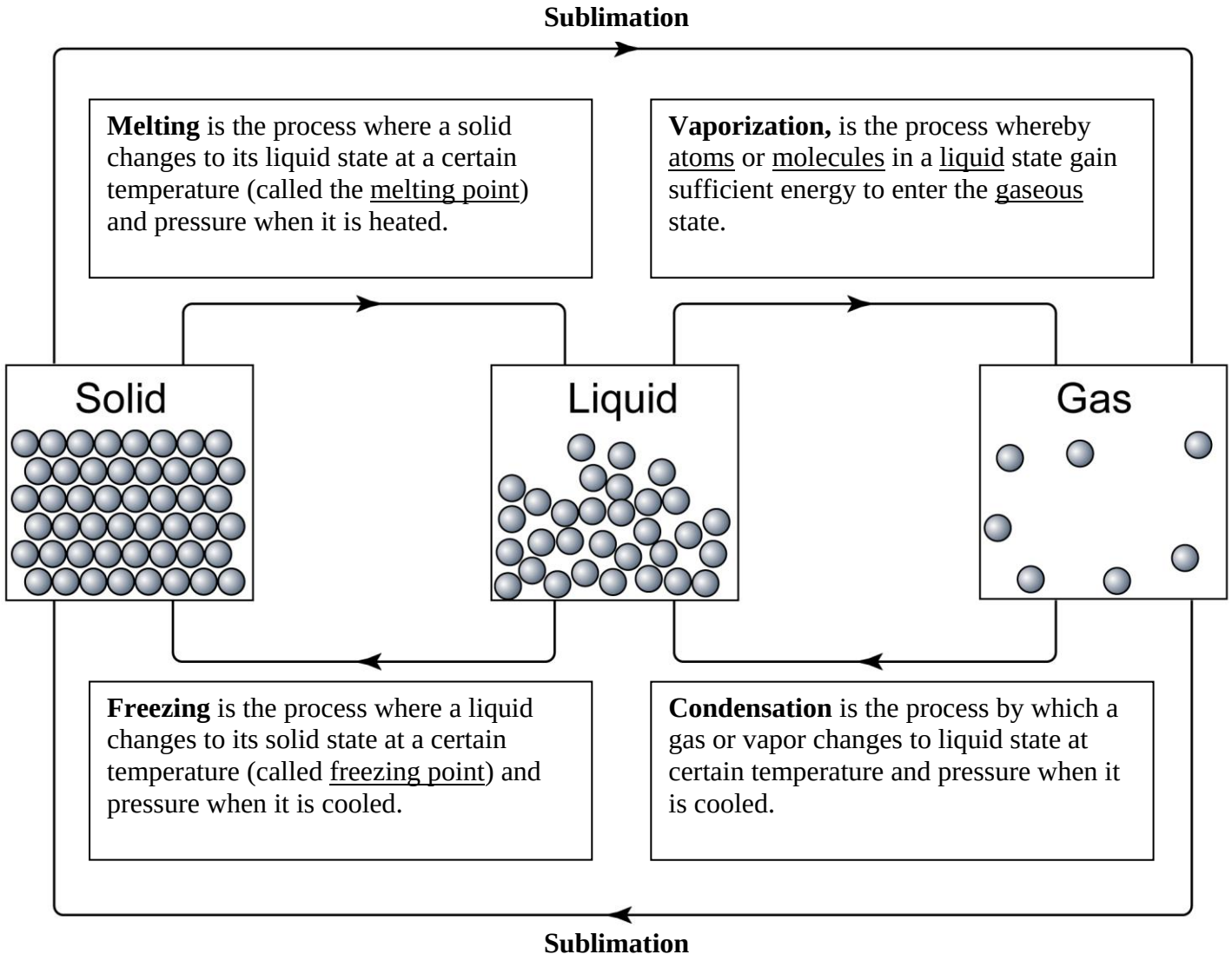
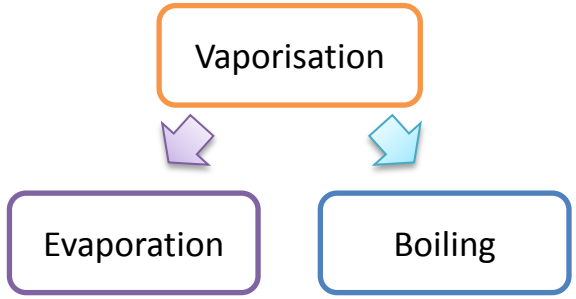
Inter-conversion between States of Matter





Boiling is the vaporization of a liquid at a certain temperature (the boiling point) and pressure when heat is applied to it.
Evaporation is the process of converting a substance (such as water) from its liquid state to its gaseous state at temperature lower than the boiling point of the liquid.

Sublimation

1. **Sublimation** is a process of conversion of a substance from the solid to the vapour state without its becoming liquid.
2. Substances that undergo sublimation at 1 atmospheric pressure are
   a. dry ice (Solid carbon dioxide)
   b. iodine
   c. ammonium chloride
   d. naphthalene

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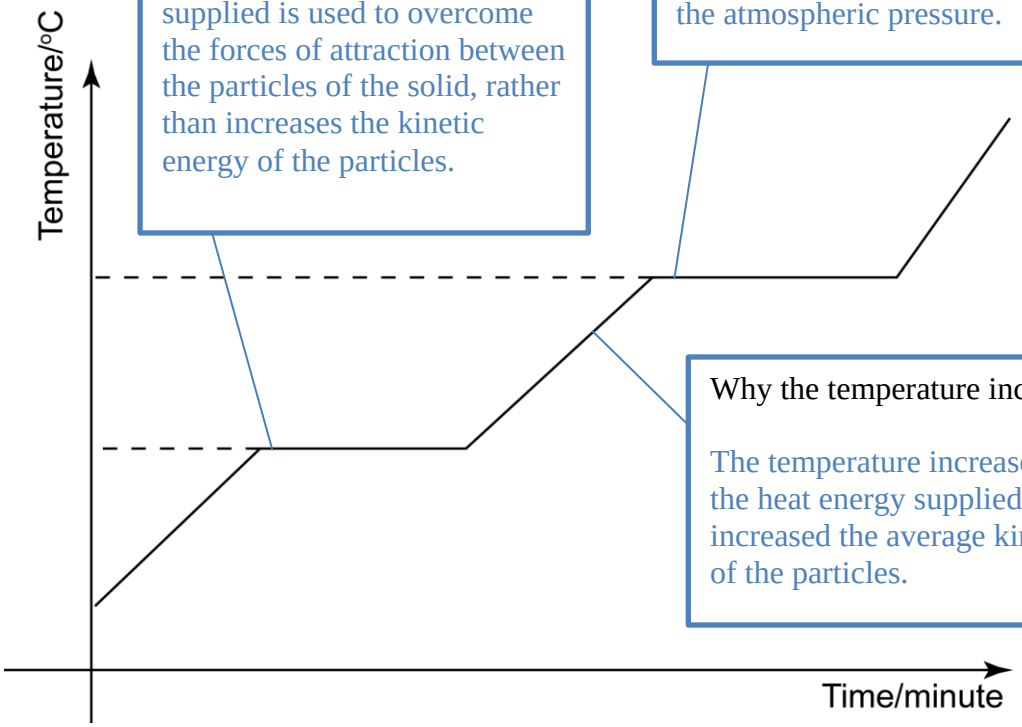
Heating Curve

Why the temperature remained unchanged?

The temperature remains unchanged because all the heat supplied is used to overcome the forces of attraction between the particles of the solid, rather than increases the kinetic energy of the particles.

Why the temperature remained unchanged?

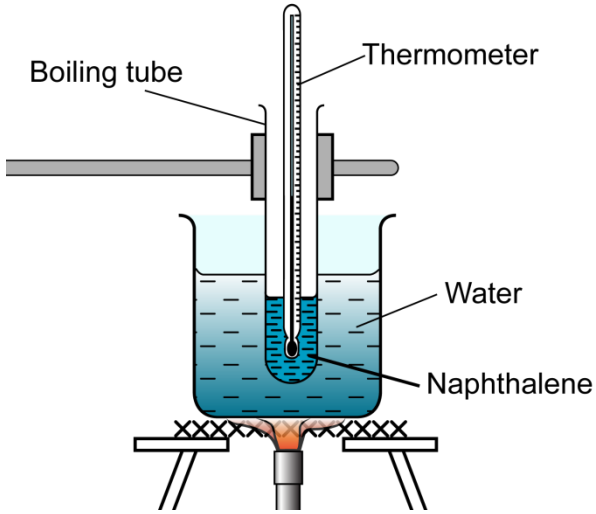
The temperature remains unchanged because the all the heat supplied is used to overcome the forces of attraction between the particles and the atmospheric pressure.



Why the temperature increases?

The temperature increases because the heat energy supplied has increased the average kinetic energy of the particles.

- **Latent heat of fusion** is the amount of thermal energy which must be absorbed or lost to change states from a solid to a liquid or vice versa.
- **Latent heat of vaporization** the amount of heat (or energy) required to completely vaporize the substance at its boiling point.



Important to know:
Water bath is used to

- ensure uniform heating
- direct heating will cause naphthalene to decompose

Naphthalene is stirred to ensure the substance is heated evenly.

Notes:

- If the boiling point of a substance is less 100°C, water bath is used.
- If the boiling point of a substance is higher than 100°C, oil bath or sand bath is used.

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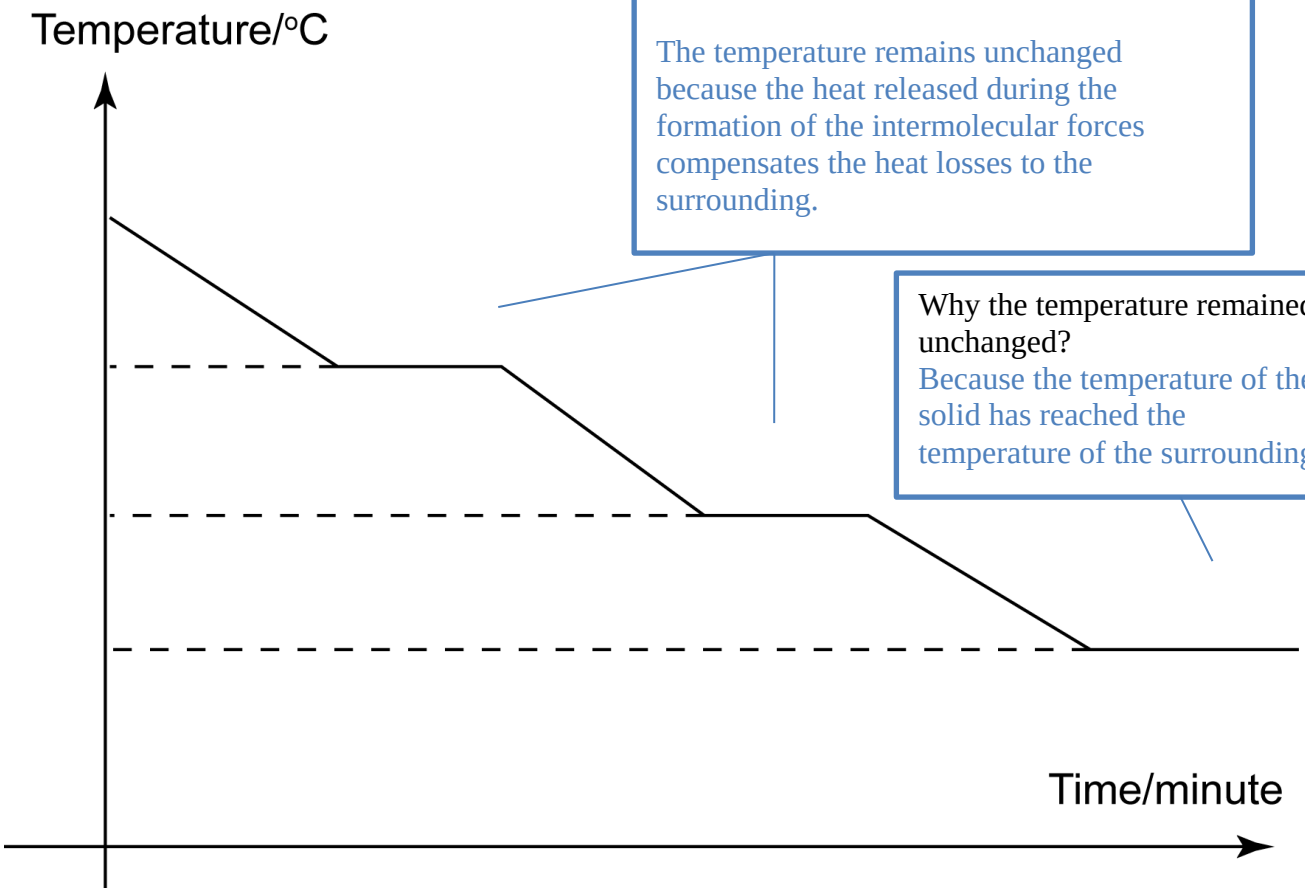
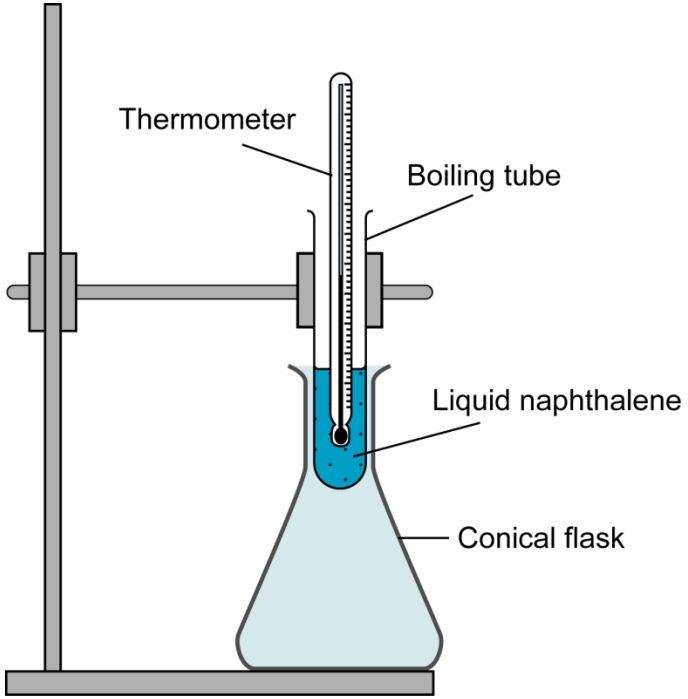
Cooling Curve



Why the temperature remained unchanged?

The temperature remains unchanged because the heat released during the formation of the intermolecular forces compensates the heat losses to the surrounding.

Why the temperature remained unchanged?
Because the temperature of the solid has reached the temperature of the surrounding.



1. Conical flask is used to
   - reduce the interference from the wind.
   - ensure uniform cooling because the air trapped in the conical flask can act as a poor conductor of heat.
2. The substance is also stirred to ensure uniform cooling.
3. If conical flask is not used and the substance is not stirred, **supercooling** may happen to the substance.

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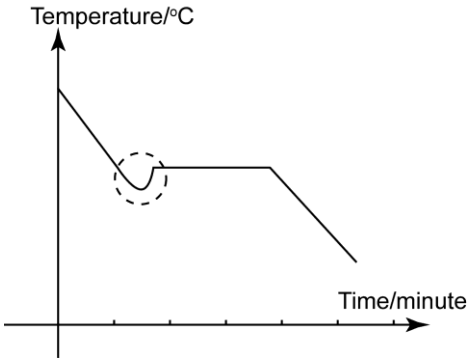

Super-cooling
Super-cooling is the cooling of a liquid to below its freezing point but keeping it in liquid state.

Supercooling

Super-cooling is the cooling of a liquid to below its freezing point but keeping it in liquid state. Supercooling is possible because of the lack of solid particles around which crystals can form.

Reference
http://en.wikipedia.org/wiki/Supercooling
http://www.bbc.co.uk/dna/h2g2/A305399

Exercise

1. If the melting point and boiling point of substance M is 50^{o}C and 120^{o}C respectively, sketch the graph of heating of substance Y from room temperature (25^{o}C) to 150^{o}C. In your graph, label the melting pint and boiling point.

2. Given that the boiling point of naphthalene is 100^{o}C and the freezing point is 80^{o}C, Sketch the cooling curve of naphthalene when naphthalene is cooled from 90oC to room temperature.

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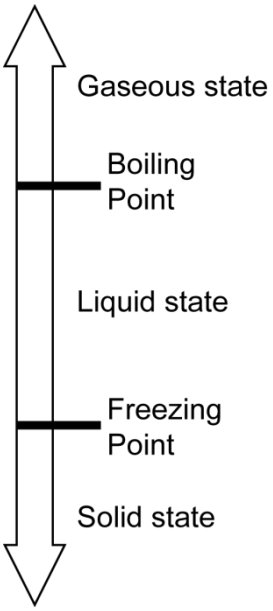

Melting Point, Boiling Point and State of Matter

The physical state of a substance at certain temperature and pressure depends on its melting point and boiling points.

1. A substance is in solid state its temperature is below its melting point.
2. It is in liquid state if its temperature is higher than its melting point but below its boiling point.
3. It is in gaseous state if its temperature is higher than its boiling point.

Exercise

1. Substance X exists as a liquid at a temperature of 85°C. What is the most likely melting point and boiling point of substance X?

	Melting point (^oC)	Boiling point (^oC)
A	-15	35
B	-5	400
C	90	300
D	40	80

Melting Point is the temperature at which the solid and liquid forms of a pure substance can exist in equilibrium.

2. Define melting point, boiling point and freezing point.

Boiling Point is the temperature at which the pressure exerted by the surroundings upon a liquid is equalled by the pressure exerted by the vapour of the liquid.

3. What is meant by supercooling?

Super cooling is the cooling of a liquid to below its freezing point but keeping it in liquid state.

4. Give two conditions for supercooling to occur.

The substance is very pure. (Lack of solid particles around which crystals can form.)
The liquid is not stirred during the cooling process.

Freezing Point is the temperature at which a liquid becomes a solid.

5. Sketch the curve you would expect if a pure liquid naphthalene is cooled quickly without stirring.

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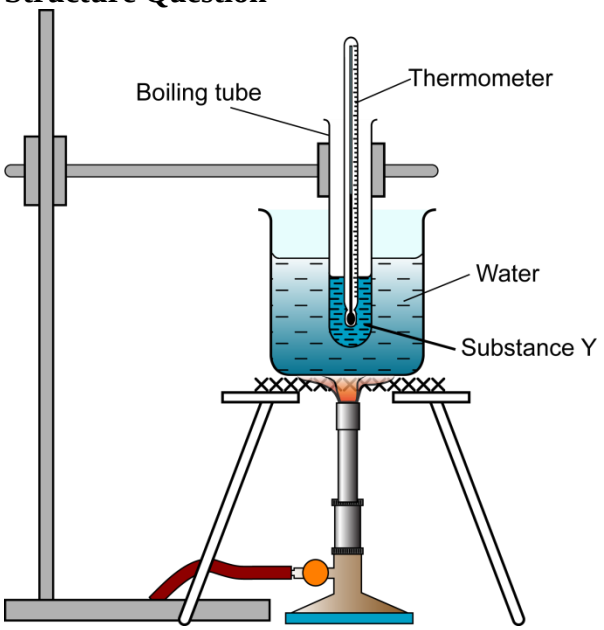
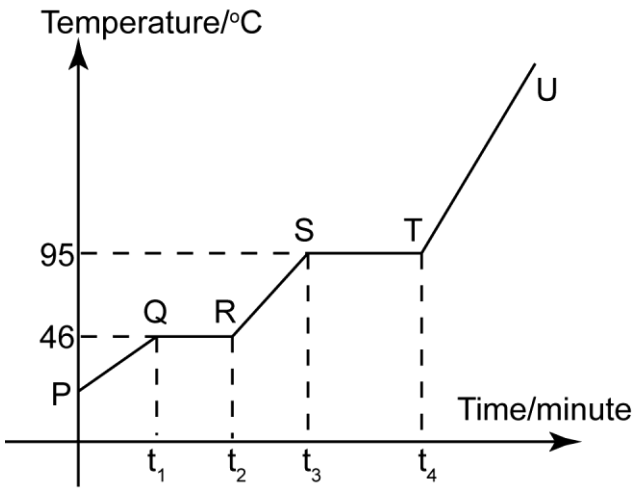
Structure Question



(a)



(b)

1. Figure (a) shows the set-up of apparatus to investigate the heating process of substance Y. In this experiment, solid substance Y was heated in a water bath from room temperature until it turned into gas. Substance Y was stirred throughout the whole experiment. The temperature of substance Y was recorded at fixed intervals of time and the graph of temperature against time during the heating of substance Y is shown in figure (b) above.
   a. What is the physical state of naphthalene at the region
      i. QR solid and liquid
      ii. ST liquid and gas
      iii. TU Gas only

   b. What is the time when substance Y begins to melt? [1 mark]
      t_1
   c. What is the boiling point of substance Y? [1 mark]
      95^oC
   d. Why the temperature of M remains unchanged from time t_3 to t_2 even though heating continues?
      From t_1 to t_2, substance Y is melting.
      The heat supply to the substance is used to overcome the strong attraction force between the solid particles.
      No heat energy is used to increase the kinetic energy (temperature) of the particles.
   e. Why water bath is used for heating the solid of substance Y?
      To ensure uniform heating on substance-Y
   f. Give a reason why water bath is suitable in this experiment?
      Because the melting point and boiling point of substance Y is lower than the boiling point of water.

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g. Name 2 substance, whose boiling point can be determined by using water bath.
Alcohol and ether

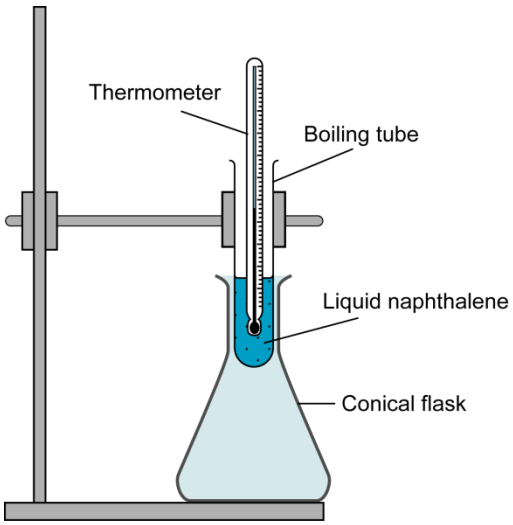
h. Given that the boiling point of substance X is around 105°C. Why can't we use water bath to determine the boiling point of substance Y?
The boiling point of water is 100°C, which means the maximum temperature that can be achieved by water is 100°C, which is lower than the boiling point of substance-X.
Substance X can not be boiled by using water bath.

i. Suggest another method which can replace water bath in this experiment.
Use oil bath or sand bath instead of water bath.

j. Why stirring of substance Y is required throughout the whole experiment?
So that heat is spread evenly throughout the substance.

k. Compare the kinetic energy of particles of substance Y at t_1 and t_3.
The kinetic energy of particles at t_3 is higher than the kinetic energy of particles at t_1.

l. State one different in the arrangement of the particles of substance Y before t_1 and after t_4.
Before t_1, particles are arrange in an orderly manner and close to one another.
After t_4, the particles are very far apart and randomly arrange.



2. The above diagram shows the apparatus used in an experiment to determine the freezing point of liquid naphthalene. The liquid naphthalene is cooled from 100°C in a conical flask and it is stirred continuously with a thermometer. The temperature of liquid naphthalene is recorded in every 30 seconds. The results obtained are tabulated below.

Time (s)	0	30	60	90	120	150	180	210	240	270	300
Temperature (°C)	100	93	85	78	78	78	78	60	43	25	25

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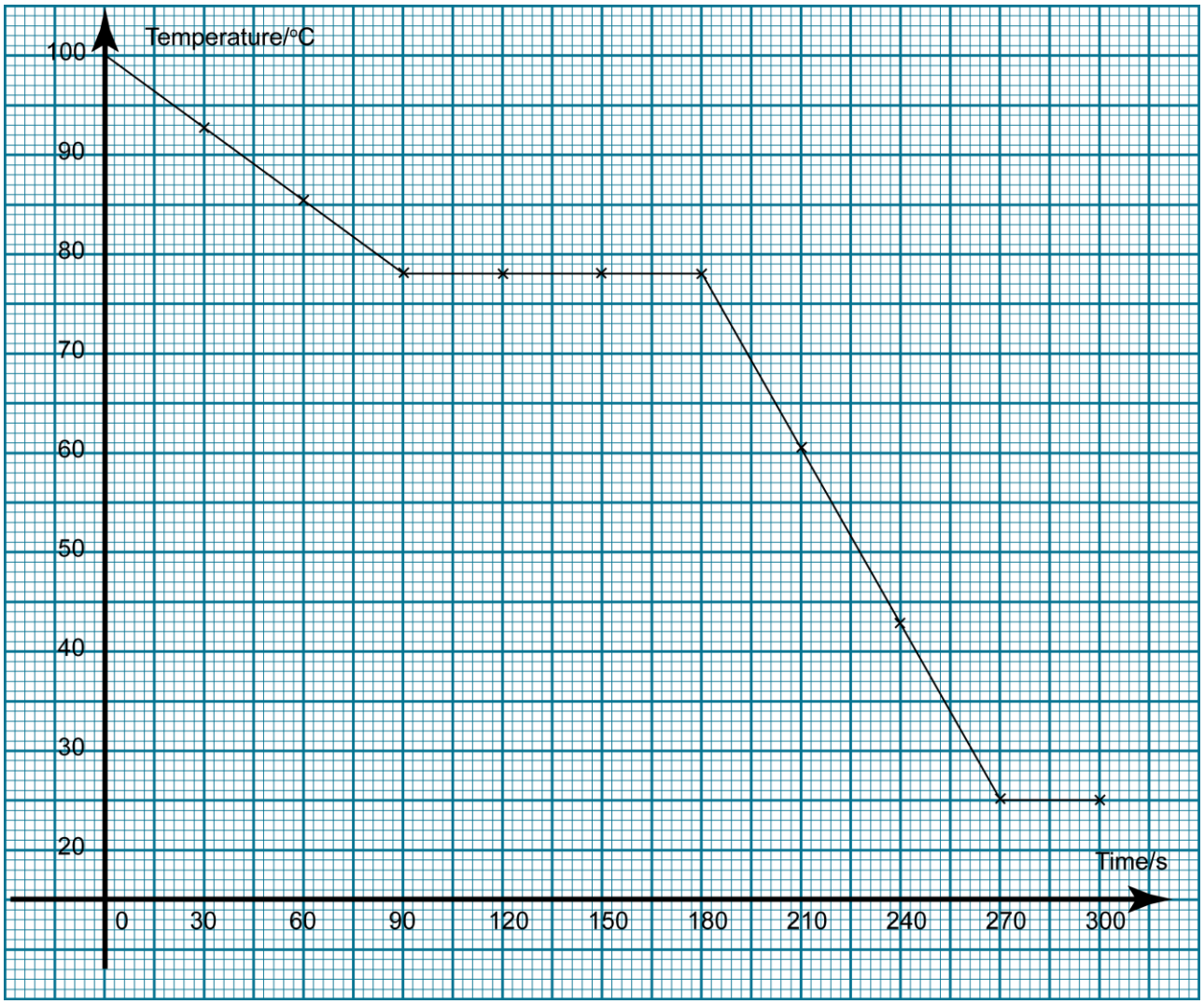
a. Draw a graph of temperature against time for the cooling of liquid naphthalene. [2 marks]



b. Determine the freezing point of liquid naphthalene from the graph.

78°C

c. What is the physical state of naphthalene at

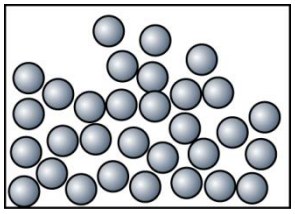
i. liquid

ii. liquid and solid

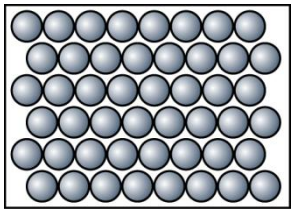
iii. solid

d. Draw the particles arrangement of naphthalene at

(i)



(iii)



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e. Explain why the temperature remains constant between 3 and 6 minutes? [1 mark]
From the time 90 second to 180 second, naphthalene is freezing.
During freezing, bonds are formed in between the molecules and energy is released.
The energy lost to the surrounding is compensated by the energy released from the formation of the bonds.

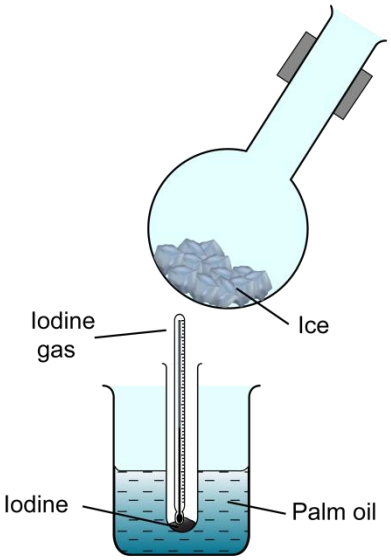
f. Explain why the boiling tube is placed inside a conical flask during the cooling process.
To ensure constant cooling at slow rate for naphthalene. This can avoid super cooling.

g. Give a reason why naphthalene needs to be stirred continuously during the process?
To avoid super cooling.

h. Will the melting point of naphthalene differ if it is contaminated by other substance?
Yes
[1 mark]

i. Sketch a graph obtained when solid naphthalene is heated from room temperature (25^{o}C) to 100^{o}C.

[2 marks]



3. An experiment is conducted to study the change of state of iodine. Some powder of solid iodine is heated as shown in the Figure above, the black solid iodine changes into a purple gas at 125^{o}C. The purple gas is then cooled by a round bottom flask that fill with ice.

a. State the process of change of state demonstrated by iodine at 125^{o}C.
Sublimation

b. What can be observed at part R?
Some black powder form at the bottom of the flask.

c. What is the name of the process when iodine gas turns into iodine solid again?
Reverse/inverse sublimation

d. Explain why palm oil is used in the experiment instead of water.
Because iodine sublime at 125^{o}C, the temperature which is higher than the boiling point of water.

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e. Name two other substances which also sublime at atmospheric pressure (1atm).
Ammonium chloride, carbon dioxide, naphthalene.

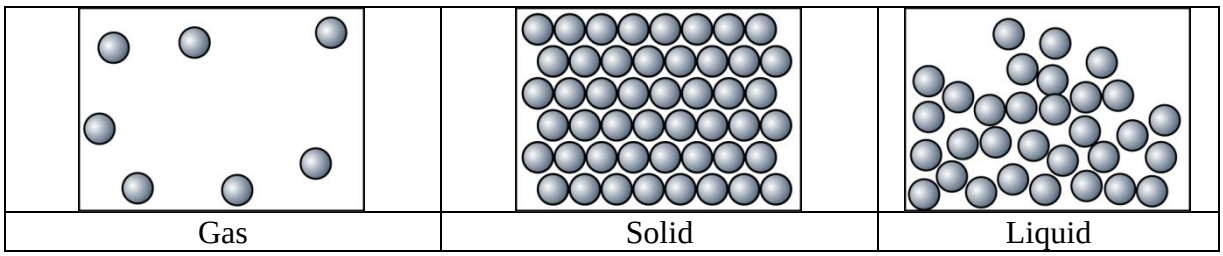
4. Table below shows the melting and boiling points of three different substances.

Substance	Melting Point	Boiling Point
H	-120°C	-5°C
I	45°C	98°C
J	10°C	350°C

a. What is the physical state of H, I and J at room temperature (25°C)?
H: gas I: solid J: liquid

b. Which substance diffuses fast at room temperature? Explain why.
I. Because I exist as gas at room temperature, there is a lot of empty space between the particles. Other than that, the particles of I have highest kinetic energy.

c. Draw a diagram show how the arrangement of the particles of I at 40°C, 80°C and 120°C.



d. What is the process during which atoms or molecules of a substance in a liquid state gain sufficient energy to enter the gaseous state below boiling point.
evaporation

e. Define boiling point.
Boiling Point is the temperature at which the pressure exerted by the surroundings upon a liquid is equalled by the pressure exerted by the vapour of the liquid.

f. Sketch the graph of temperature against time for substance I when it s cooled from 120°C to room temperature.