

4.4 Gas Laws

Pressure, Temperature and Volume of Gas

Photograph 4.3 shows an air cushion wrap used in packaging of goods. When it is compressed, the air inside gives resistance. This observation can be explained in terms of the behaviour of gas molecules based on the Kinetic Theory of Gas.



Photograph 4.3 Air cushion wrap being compressed



Activity 4.9

ISS ICS

Aim: To observe the behaviour of gas molecules through computer simulation

Instructions:

1. Carry out a Think-Pair-Share activity.
2. Scan the QR code to see the simulation on the behaviour of gas molecules. Based on the simulation, discuss:
 - (a) movement of gas molecules
 - (b) space filled by gas molecules
 - (c) direction of motion of molecules
 - (d) collisions between gas molecules and the walls of the container
 - (e) effects of increasing and decreasing of pressure, temperature and volume of gas on the behaviour of the gas molecules
3. Present your findings.

Simulation of behaviour of gas molecules



<http://bt.sasbadi.com/p4148>

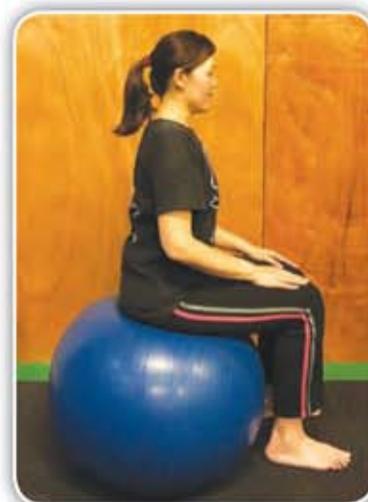
Table 4.8 explains pressure, temperature and volume of gas in a closed container based on the Kinetic Theory of Gas.

Table 4.8 Pressure, temperature and volume of gas based on the Kinetic Theory of Gas

Characteristic of gas	Description
Pressure	<ul style="list-style-type: none">• Gas molecules always move randomly.• When gas molecules collide with the wall of the container and rebound, a force is exerted on the wall of the container.• Force per unit area is the pressure of the gas.
Temperature	<ul style="list-style-type: none">• Average kinetic energy of gas molecules increases with temperature.
Volume	<ul style="list-style-type: none">• Gas molecules move freely and fill the entire space of the container.• Volume of gas is the same as the volume of its container.

Table 4.9 S.I. unit and other units for pressure, temperature and volume of gas

Quantity	S.I. unit	Symbol for S.I. unit	Other units
Pressure, P	pascal	Pa	cm Hg
Temperature, T	kelvin	K	°C, °F
Volume, V	(metre) ³	m ³	mm ³ , cm ³ , mℓ



Photograph 4.4 Exercise ball being compressed

Relationship between Pressure and Volume of Gas

Photograph 4.4 shows an exercise ball being compressed when someone sits on it. What happens to the air pressure inside the ball?



Experiment

4.4

Inference: Volume of gas influences pressure of gas

Hypothesis: The smaller the volume of gas, the higher the gas pressure

Aim: To determine the relationship between volume and pressure of a fixed mass of gas at constant temperature

Variables:

- (a) Manipulated variable: Volume, V
- (b) Responding variable: Pressure, P
- (c) Constant variable: Temperature and mass of air

Apparatus: 100 mℓ syringe, rubber tube, pressure gauge and retort stand

Procedure:

1. Set up the apparatus as shown in Figure 4.24.

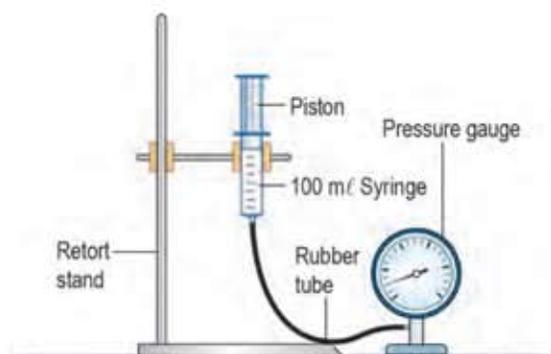


Figure 4.24

DIY

Visit the following websites to carry out virtual experiments on Boyle's Law



<http://bt.sasbadi.com/p4149a>



<http://bt.sasbadi.com/p4149b>

- Adjust the piston so that the volume of air in the syringe is 100 mL. Then, connect the end of the syringe to a pressure gauge.
- Take initial readings of the volume and pressure of the air in the syringe. Record the readings in Table 4.10.
- Push the piston slowly until the volume of air in the syringe becomes 90 mL. Take the reading of the air pressure and record it in the table.
- Repeat step 4 with volumes 80 mL, 70 mL and 60 mL.
- Record all pressure, P in Table 4.10.

Results:

Table 4.10

Volume, V / mL	Pressure, P / kPa	$\frac{1}{V} / \text{mL}^{-1}$
60		
70		
80		
90		
100		

Analysis of data:

Plot a graph of pressure, P against volume, V and a graph of P against $\frac{1}{V}$.

Conclusion:

What conclusion can be made from this experiment?

Prepare a complete report on this experiment.

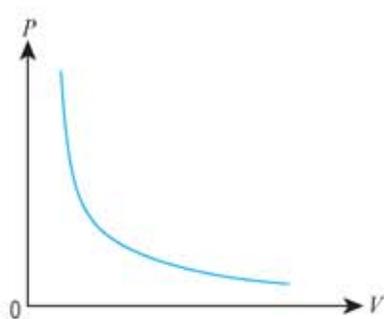
Discussion:

- Why is a syringe of larger volume used?
- Why is the piston pushed slowly into the syringe?

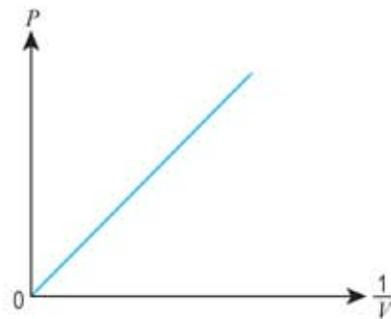


Experiment 4.4 shows that gas pressure increases when the volume of gas decreases. What is the relationship between pressure and volume of gas at constant temperature?

Figure 4.25 shows the relationship between pressure and volume of gas.



(a) Graph P against V



(b) Graph P against $\frac{1}{V}$

Figure 4.25 Relationship between pressure and volume of gas

Graph of P against V shows that pressure decreases with volume. Graph of P against $\frac{1}{V}$ however shows a straight line passing through the origin. This shows that pressure is inversely proportional to volume.

Boyle's Law states that pressure is inversely proportional to volume for a fixed mass of gas at constant temperature.

$$P \propto \frac{1}{V}$$

$$P = k\left(\frac{1}{V}\right)$$

Where k is a constant

P = gas pressure (Pa)

V = gas volume (m^3)

As such, $PV = k$

If a gas experiences a change in pressure and volume from condition 1 to condition 2,

since $PV = k$, condition 1 of gas, $P_1V_1 = k$

condition 2 of gas, $P_2V_2 = k$

therefore, $P_1V_1 = P_2V_2$



INTEGRATION OF HISTORY



Robert Boyle (1627–1691) is a scientist who emphasised the use of scientific method when carrying out investigations. Through data from experiments, he concluded that the volume of gas is inversely proportional to its pressure.



<http://bt.sasbadi.com/p4151a>

Boyle's Law



<http://bt.sasbadi.com/p4151b>

Figure 4.26 shows a fixed mass of gas compressed at constant temperature. When the volume of gas decreases, the same number of molecules move in a smaller space. Therefore, the number of molecules per unit volume increases. This causes the rate of collisions between molecules and the walls of the container to increase. Force per unit area on the wall of the container also increases. As such, gas pressure increases.

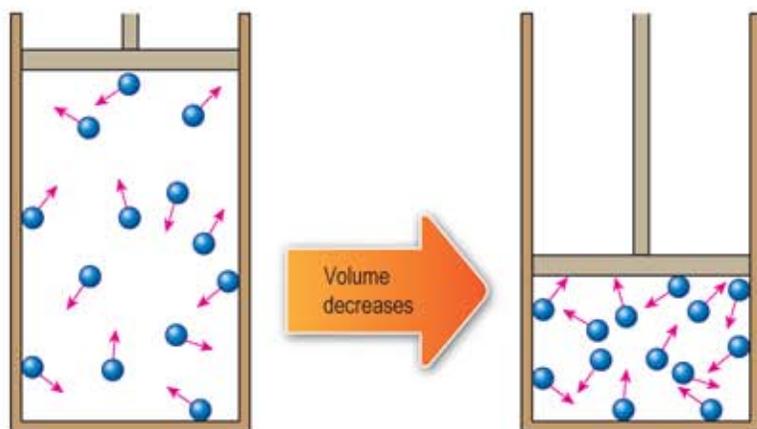
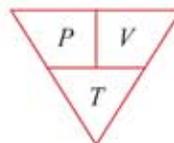


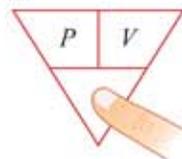
Figure 4.26 Fixed mass of a gas compressed at constant temperature

SMART INFO

PVT triangle:



For Boyle's Law, temperature is constant.



$PV = \text{constant}$

$$P_1V_1 = P_2V_2$$

Example 1

Air in a closed syringe has a volume of 60 cm^3 and pressure of 108 kPa . The piston of the syringe is pushed to compress the air to a volume of 48 cm^3 . Calculate the pressure of the compressed air.

Solution:

Step 1

List the given information in symbols.

$$\begin{cases} P_1 = 108 \text{ kPa} \\ P_2 = \text{compressed air pressure} \\ V_1 = 60 \text{ cm}^3 \\ V_2 = 48 \text{ cm}^3 \end{cases}$$

Step 2

Identify and write down the formula used.

$$\begin{cases} \text{Temperature of gas does not change.} \\ \text{Boyle's Law formula is used.} \\ P_1V_1 = P_2V_2 \end{cases}$$

Step 3

Substitute numerical values into the formula and perform the calculations.

$$\begin{cases} 108 \times 60 = P_2 \times 48 \\ P_2 = \frac{108 \times 60}{48} \\ = 135 \text{ kPa} \end{cases}$$

Relationship between Volume and Temperature of Gas

Photograph 4.5 shows an empty plastic bottle filled with air in a refrigerator. What happened to the volume of air in the bottle?



(a) Empty plastic bottle before being cooled



(b) Empty plastic bottle after being cooled

Photograph 4.5 Condition of plastic bottle in refrigerator before and after being cooled



Experiment

4.5

Inference: Temperature of a gas influences the volume of gas

Hypothesis: The higher the temperature, the larger the volume of gas

Aim: To determine the relationship between temperature and volume of a fixed mass of gas at constant pressure

Variables:

(a) Manipulated variable: Temperature, θ

(b) Responding variable: Volume, V represented by length of column of air, L in capillary tube

(c) Constant variable: Pressure and mass of air

Apparatus: Capillary tube containing air trapped by a column of concentrated sulphuric acid, 500 ml beaker, thermometer, ruler, Bunsen burner, tripod stand, wire gauze, stirrer and retort stand

Materials: Water, ice and rubber band

Procedure:

1. Set up the apparatus as shown in Figure 4.27.

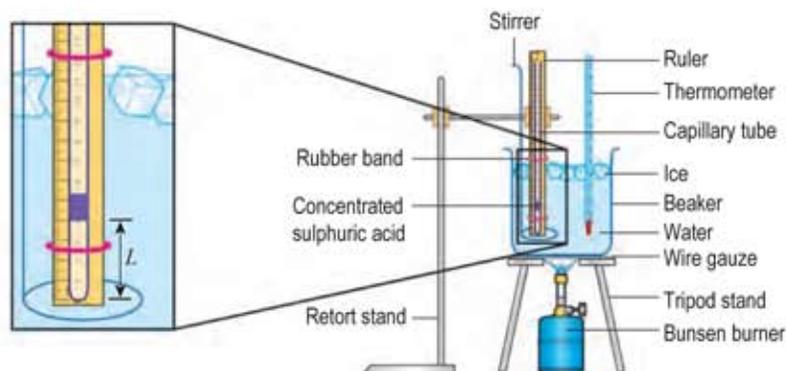


Figure 4.27

- Heat the water slowly and stir it continuously until the temperature of the water reaches 30°C .
- Take the reading of the column of air, L in the capillary tube. Record the reading in Table 4.11.
- Repeat steps 2 and 3 for temperatures 40°C , 50°C , 60°C , 70°C and 80°C .
- Record all lengths of column of air, L in Table 4.11.

Results:

Table 4.11

Temperature, $\theta / ^{\circ}\text{C}$	Length of column of air, L / cm
30	
40	
50	
60	
70	
80	

Analysis of data:

- Plot a graph of length of column of air, L against temperature, θ . θ -axis has to cover the range of 0°C to 100°C .
- Extrapolate graph of L against θ until $\theta = 0^{\circ}\text{C}$.
- Plot another graph of L against θ with θ -axis covering the range of -300°C to 100°C .
- Extrapolate graph of L against θ until $L = 0 \text{ cm}$.

Conclusion:

What conclusion can be made from this experiment?

Prepare a complete report on this experiment.

Discussion:

- Why must the water be continuously stirred while being heated?
- What assumption needs to be made so that the length of the column of air trapped in the capillary tube can represent the volume of the trapped air?

[Key: Volume of column of air, $V = \text{length of column of air, } L \times \text{cross sectional area of capillary tube, } A]$

Volume of gas increases when the temperature of the gas rises. At 0°C , the air trapped in the capillary tube still has a certain volume. This shows that at 0°C , gas molecules are still moving and filling up the space in the container.

Figure 4.28 shows the graph of V against θ extrapolated until $V = 0 \text{ cm}^3$.

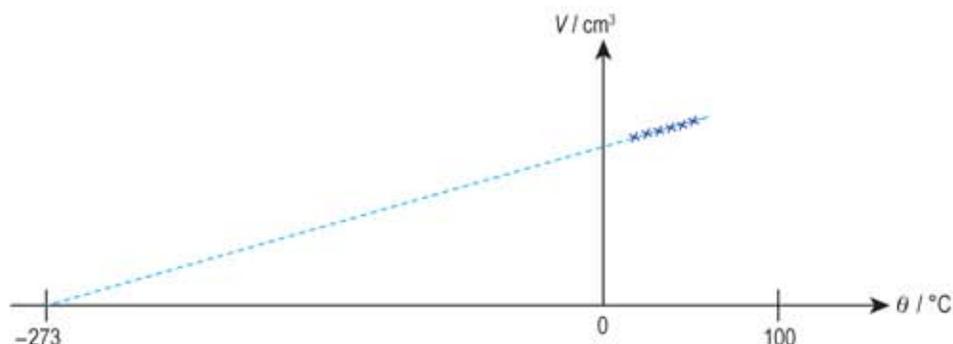


Figure 4.28 Extrapolation of graph V against θ

At temperature of -273°C , gas molecules no longer move and are unable to fill the space. As such, volume of gas becomes zero. The temperature of -273°C is the lowest temperature possible and is known as absolute zero. On the kelvin scale, absolute zero is given the value 0 kelvin or 0 K. Temperature that is stated in unit kelvin is absolute temperature.

Table 4.12 Temperature in units of degree Celsius, $^\circ\text{C}$ and kelvin, K for three temperature points

Temperature point	Temperature, $\theta / ^\circ\text{C}$	Temperature, T / K
Absolute zero	-273	0
Melting ice	0	273
Steam	100	373

Conversion of units between degree Celsius, $^\circ\text{C}$ and kelvin, K can be done using the following equation:

$$T = \theta + 273$$

For $\theta^\circ\text{C}$ and $T \text{ K}$

Figure 4.29 shows the graph of V against T .

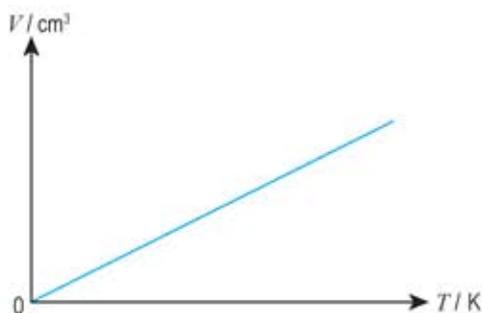


Figure 4.29 Graph of V against T for a gas

The graph of V against T for gas shows a straight line passing through the origin. This shows that the volume of gas is directly proportional to absolute temperature.

INTEGRATION OF HISTORY



Jacques Charles (1746–1823) a French physicist and chemist investigated how the volume of gas depends on the temperature of gas. He built the first hydrogen balloon and succeeded in raising the balloon to a height of 3.2 km.



<http://bt.sasbadi.com/p4155>

Charles' Law states that volume is directly proportional to absolute temperature for a fixed mass of gas at constant pressure.

$$V \propto T$$

$$V = kT$$

where k is a constant

T = absolute temperature (K)

V = volume of gas (m^3)

As such, $\frac{V}{T} = k$

If a gas experiences a change in volume and temperature from condition 1 to condition 2,

since $\frac{V}{T} = k$, condition 1 of gas: $\frac{V_1}{T_1} = k$

condition 2 of gas: $\frac{V_2}{T_2} = k$

therefore, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

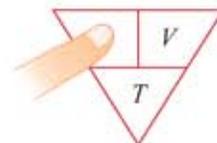
Charles' Law



<http://bt.sasbadi.com/p4156>

SMART INFO

For Charles' Law, pressure is constant.



$$\frac{V}{T} = \text{constant}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Figure 4.30 shows a fixed mass of gas being heated at constant pressure. When the temperature of the gas increases, the average kinetic energy of its molecules increases, and the molecules move with higher velocity. To keep a constant gas pressure, the volume of gas increases so that the rate of collision of gas molecules with the walls of the container is unchanged.

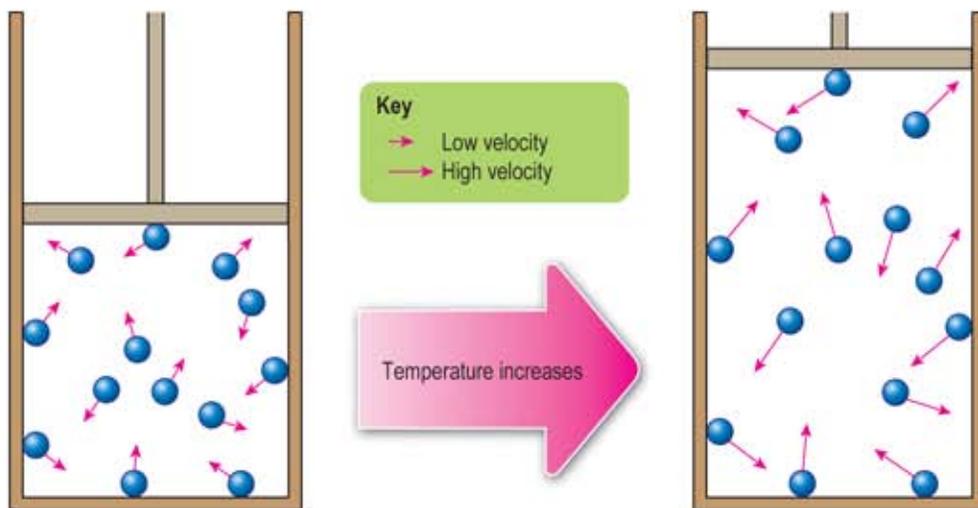


Figure 4.30 Fixed mass of gas heated at constant pressure

Example 1

An air bubble has a volume of 1.2 cm^3 at a temperature of 27°C . What is the volume of the air bubble if its temperature increases to 47°C ?

Solution:**Step 1**

List the given information in symbols.

$$\left\{ \begin{array}{l} V_1 = 1.20 \text{ cm}^3 \\ V_2 = \text{Final volume of air} \\ T_1 = (27 + 273) = 300 \text{ K} \\ T_2 = (47 + 273) = 320 \text{ K} \end{array} \right.$$

Step 2

Identify and write down the formula used.

$$\left\{ \begin{array}{l} \text{Gas pressure is constant.} \\ \text{Charles' Law formula is used.} \\ \frac{V_1}{T_1} = \frac{V_2}{T_2} \end{array} \right.$$

Step 3

Substitute numerical values into the formula and perform the calculations.

$$\left\{ \begin{array}{l} \frac{1.2}{300} = \frac{V_2}{320} \\ V_2 = \frac{1.2 \times 320}{300} \\ = 1.28 \text{ cm}^3 \end{array} \right.$$

Relationship between Pressure and Temperature of Gas

Photograph 4.6 shows air pressure in the tyre of a car being measured on a hot day. The driver of the car touched the tyre after the journey and found that the tyre is hotter than before the journey. Photograph 4.7 shows the readings of the pressure gauge before and after the journey. What happened to the air pressure inside the tyre?



Photograph 4.6 Air pressure of tyre being measured



(a) Before journey



(b) After journey

Photograph 4.7 Readings of air pressure



Experiment

4.6

Inference: Temperature of gas influences pressure of gas

Hypothesis: The higher the temperature, the higher the gas pressure

Aim: To determine the relationship between temperature and pressure for a fixed mass of gas at constant volume

Variables:

(a) Manipulated variable: Temperature, θ

(b) Responding variable: Pressure, P

(c) Constant variable: Volume and mass of air

Apparatus: Round-bottom flask, large beaker, thermometer, pressure gauge, Bunsen burner, wire gauze, tripod stand, stirrer, retort stand and wooden block

Materials: Water and ice

Procedure:

1. Set up the apparatus as shown in Figure 4.31.

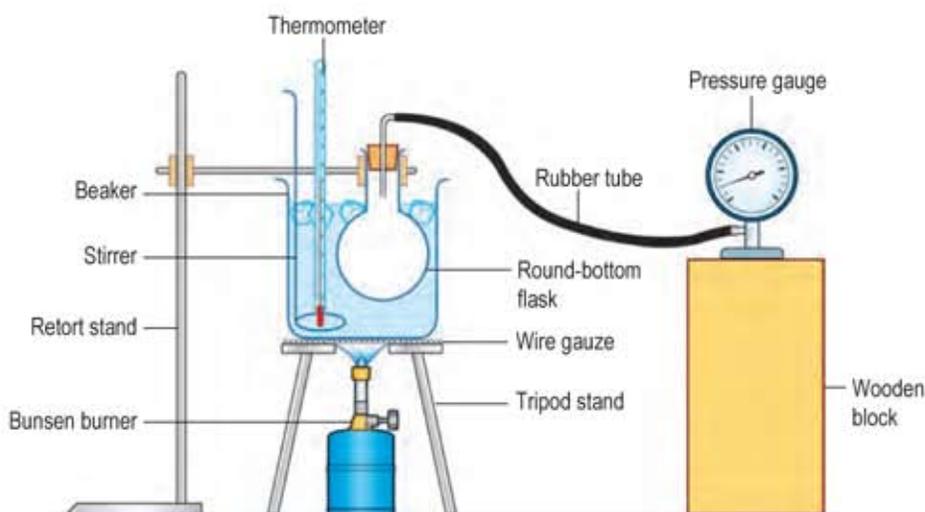


Figure 4.31

- Heat the water slowly and stir it continuously until the temperature of the water reaches 30°C .
- Take the reading of the air pressure, P inside the flask. Record the reading in Table 4.13.
- Repeat steps 2 and 3 with temperatures 40°C , 50°C , 60°C , 70°C and 80°C .
- Record all readings of air pressure, P in Table 4.13.

Results:

Table 4.13

Temperature, $\theta / ^\circ\text{C}$	Air pressure, P / kPa
30	
40	
50	
60	
70	
80	

Analysis of data:

1. Plot a graph of pressure, P against temperature, θ . θ -axis has to cover the range of -300°C to 100°C .
2. Extrapolate the graph until $P = 0 \text{ kPa}$. Determine the temperature when $P = 0 \text{ kPa}$.

Conclusion:

What conclusion can be made from this experiment?

Prepare a complete report on this experiment.

Discussion:

1. What is the advantage of using a round-bottom flask to heat the air?
2. The thermometer is placed in the large beaker filled with water. What is the assumption made so that the thermometer reading is the same as the temperature of the air in the round-bottom flask?

Experiment 4.6 shows that gas pressure increases when temperature of the gas rises. Figure 4.32 shows the graph of P against θ extrapolated until $P = 0 \text{ kPa}$.

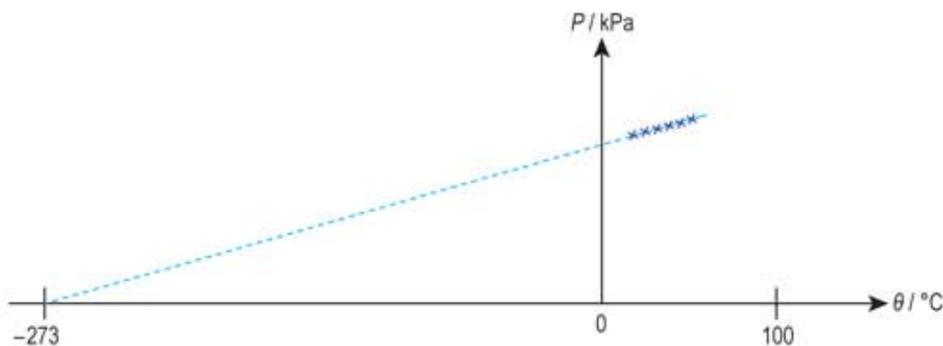


Figure 4.32 Extrapolation of graph P against θ

Graph of P against θ shows that gas pressure increases linearly when temperature of the gas rises. At 0°C , gas molecules are still moving and the gas has pressure. At -273°C (absolute zero), gas molecules no longer move and do not collide with the walls of the container. Hence, gas pressure becomes zero. Figure 4.33 shows the graph of P against T .

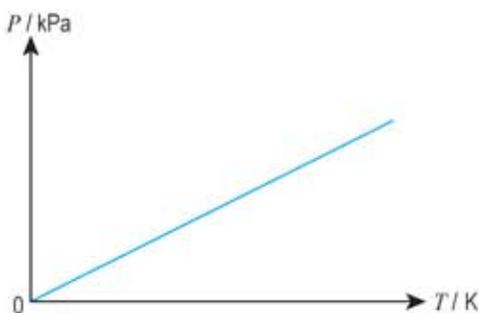


Figure 4.33 Graph of P against T

Graph of P against T of gas is a straight line through the origin. This shows that gas pressure is directly proportional to absolute temperature.

Gay-Lussac's Law states that pressure is directly proportional to absolute temperature of a fixed mass of gas at constant volume.

$$P \propto T$$

$$P = kT$$

where k is a constant

P = pressure (Pa)

T = absolute temperature (K)

As such, $\frac{P}{T} = k$

If a gas experiences change in pressure and temperature from condition 1 to condition 2,

since $\frac{P}{T} = k$, condition 1 of gas: $\frac{P_1}{T_1} = k$

condition 2 of gas: $\frac{P_2}{T_2} = k$

therefore, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

INTEGRATION OF HISTORY



Joseph Louis Gay-Lussac (1778–1850) is a French physicist and chemist who made quantitative investigation about the characteristics of gas. He also investigated the magnetic field of the Earth and composition of the atmosphere at high altitudes. In addition, he found two new elements, boron and iodine.



<http://bt.sasbadi.com/p4160a>

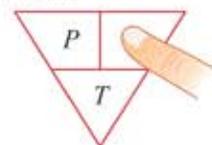
Gay-Lussac's Law



<http://bt.sasbadi.com/p4160b>

SMART INFO

For Gay-Lussac's Law, volume is constant.



$$\frac{P}{T} = \text{constant}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Figure 4.34 shows a fixed mass of gas being heated at constant volume. When the temperature of the gas increases, average kinetic energy of its molecules increases, and the molecules move with higher velocity. As the volume of gas does not change, the rate of collision of gas molecules with the walls of the container increases. Force per unit area on the wall of the container also increases. As such, gas pressure increases.

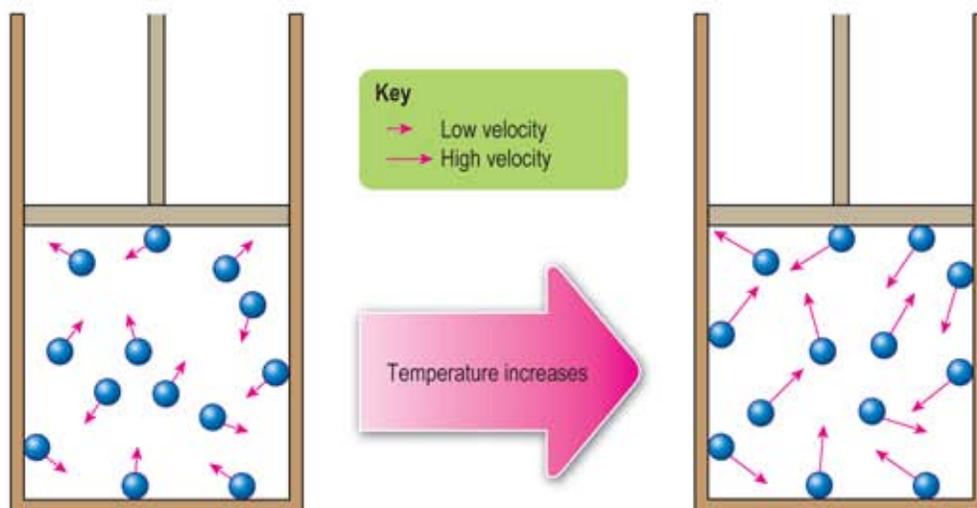


Figure 4.34 Fixed mass of gas heated at constant volume

Example 1

Gas in a closed steel cylinder has a pressure of 180 kPa at a temperature of 25°C. What is the gas pressure when the cylinder is heated to a temperature of 52°C?

Solution:

Step 1

List the given information in symbols.

$$\left\{ \begin{array}{l} P_1 = 180 \text{ kPa} \\ P_2 = \text{Final pressure of air} \\ T_1 = (25 + 273) = 298 \text{ K} \\ T_2 = (52 + 273) = 325 \text{ K} \end{array} \right.$$

Step 2

Identify and write down the formula used.

$$\left\{ \begin{array}{l} \text{Volume of gas is constant.} \\ \text{Gay-Lussac's Law formula is used.} \\ \frac{P_1}{T_1} = \frac{P_2}{T_2} \end{array} \right.$$

Step 3

Substitute numerical values into the formula and perform the calculations.

$$\left\{ \begin{array}{l} \frac{180}{298} = \frac{P_2}{325} \\ P_2 = \frac{180 \times 325}{298} \\ = 196.3 \text{ kPa} \end{array} \right.$$

Solving Problems Involving Pressure, Temperature and Volume of a Fixed Mass of Gas Using Formulae from the Gas Laws

Example 1

Photograph 4.8 shows a syringe with its nozzle closed. Air in the syringe has an initial volume of 7.5 cm^3 and pressure of 105 kPa . The air is compressed to a volume of 2.5 cm^3 . What is the pressure of the air?



Photograph 4.8

Solution:

Step 1

List the given information in symbols.

$$\left\{ \begin{array}{l} P_1 = 105 \text{ kPa} \\ P_2 = \text{compressed air pressure} \\ V_1 = 7.5 \text{ cm}^3 \\ V_2 = 2.5 \text{ cm}^3 \end{array} \right.$$

Step 2

Identify and write down the formula used.

$$\left\{ \begin{array}{l} P_1 V_1 = P_2 V_2 \end{array} \right.$$

Step 3

Substitute numerical values into the formula and perform the calculations.

$$\left\{ \begin{array}{l} 105 \times 7.5 = P_2 \times 2.5 \\ P_2 = \frac{105 \times 7.5}{2.5} \\ = 315 \text{ kPa} \end{array} \right.$$

Example 2

Air of volume 0.24 m^3 in an expandable cylinder is heated from 27°C to 77°C at constant pressure. What is the volume of the air at 77°C ?

Solution:

$$V_1 = 0.24 \text{ m}^3$$

$$V_2 = \text{Final volume of air}$$

$$T_1 = (27 + 273)$$

$$= 300 \text{ K}$$

$$T_2 = (77 + 273)$$

$$= 350 \text{ K}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{0.24}{300} = \frac{V_2}{350}$$

$$\begin{aligned} V_2 &= \frac{0.24 \times 350}{300} \\ &= 0.28 \text{ m}^3 \end{aligned}$$

Example 3

Initial pressure and temperature of air in the tyre of a car are 210 kPa and 25°C respectively. After a journey, the air pressure in the tyre is 240 kPa. Calculate the temperature of the air in the tyre in °C.

Solution:

Assume the volume of the tyre does not change. Gay-Lussac's Law is used.

$$P_1 = 210 \text{ kPa}$$

$$P_2 = 240 \text{ kPa}$$

$$T_1 = 25^\circ\text{C} + 273 \\ = 298 \text{ K}$$

$$T_2 = \text{Final temperature of air}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{210}{298} = \frac{240}{T_2}$$

$$T_2 = \frac{240 \times 298}{210} \\ = 340.6 \text{ K}$$

$$\text{Final temperature of air} = 340.6 - 273 \\ = 67.6^\circ\text{C}$$

Formative Practice 4.4

- State the physical quantities that are constant in Boyle's Law, Charles' Law and Gay-Lussac's Law.
- A syringe contains 50 cm³ of air at a pressure of 110 kPa. The end of the syringe is closed and its piston slowly pushed until the volume of air becomes 20 cm³. What is the pressure of the compressed air? 🧠
- An air bubble trapped under a leaf in a lake has a volume of 1.60 cm³ at a temperature of 38°C. Calculate the volume of the bubble if the temperature of the water in the lake drops to 26°C. 🧠
- Pressure in a gas cylinder is 175 kPa at a temperature of 27°C. Heat from a nearby furnace causes the gas pressure to increase to 300 kPa. What is the temperature of the gas inside the cylinder? 🧠
- Figure 4.35 shows an apparatus set up to study the relationship between pressure and temperature for air inside a round-bottom flask.
 - Identify four aspects in the apparatus set up that can jeopardise the accuracy of the results of the experiment. 🧠
 - Suggest modifications to improve the set up. 🧠

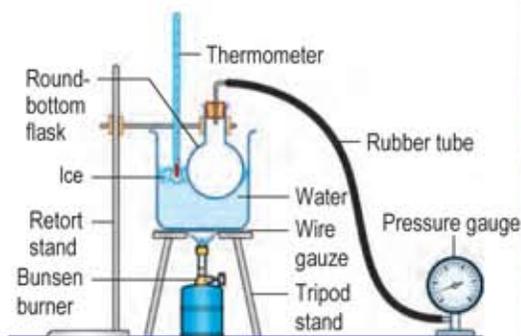
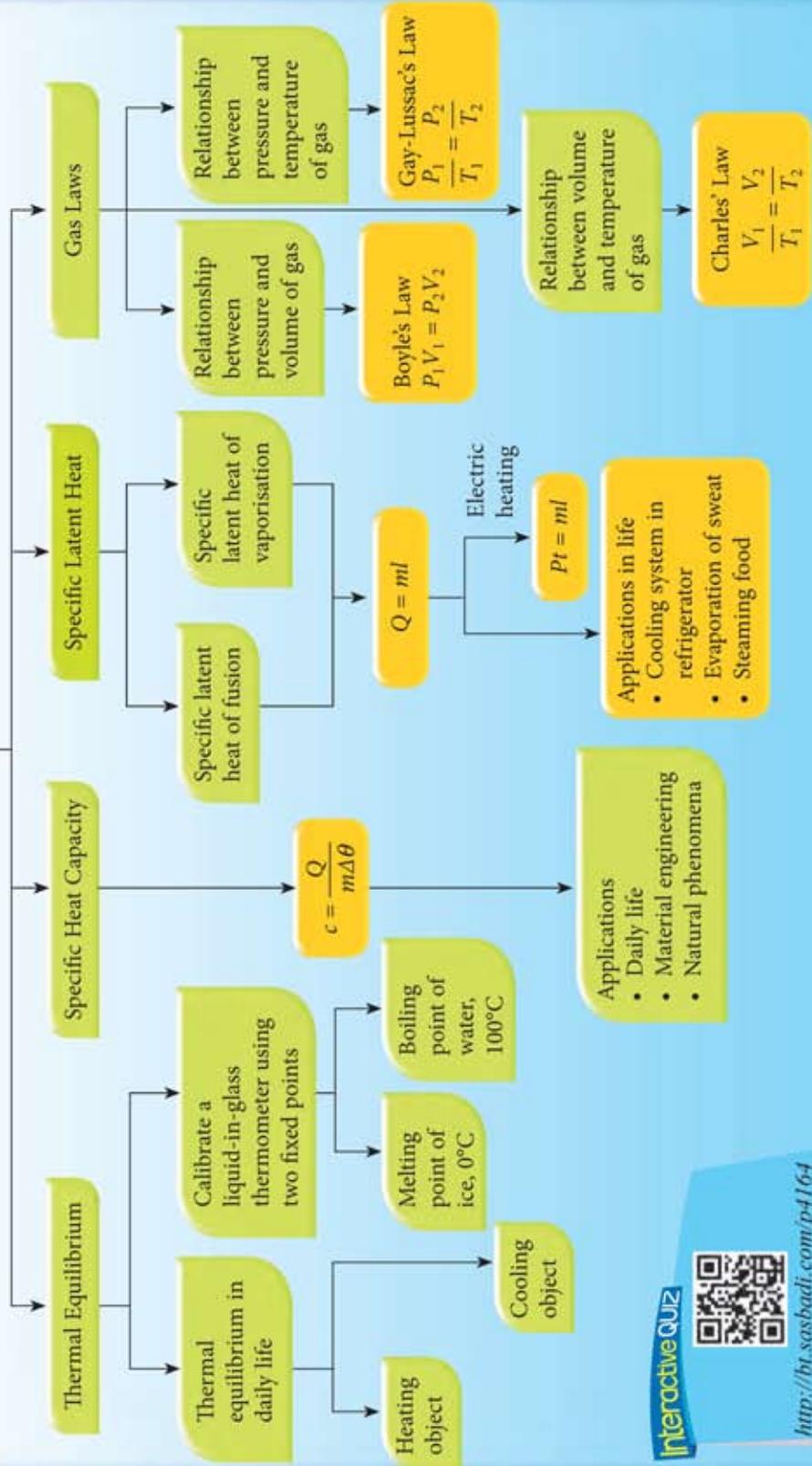


Figure 4.35

Conceptual Framework

Heat



Interactive QUIZ



<http://bt.sasbadi.com/p4164>

SELF-REFLECTION

1. New things I learnt in this chapter on heat are _____
2. The most interesting thing I learnt in this chapter on heat is _____
3. Things I still do not fully understand or comprehend are _____
4. My performance in this chapter,

Poor 😞 1 2 3 4 5 😊 Excellent
5. I need to _____ to improve my performance in this chapter.

Download and print
Self-reflection Chapter 4



<http://bt.sasbadi.com/p4165>



Performance Evaluation

1. Photograph 1 shows a steam injector machine which can inject steam into water in a container.
 - (a) What is the meaning of latent heat?
 - (b) Explain how water in the container is heated by steam injected into it.
 - (c) What is the advantage of heating water using the injection of steam?
2. Tick (✓) for situations that show thermal equilibrium.



Photograph 1

Situation	Tick (✓)
(a) A hot object and a cold object placed side by side.	
(b) An object is heated by a nearby source of fire.	
(c) Two objects at the same temperature and in contact so that heat can be transferred between them but without net heat transfer.	
(d) Two objects at the same temperature but separated by a heat barrier.	

8. Air in the tyre of a car has a pressure of 220 kPa at initial temperature of 27°C. After a race, the temperature of the air increases to 87°C.
- Calculate the air pressure in the tyre after the race. 🧠
 - What assumptions did you make in 8(a)? 🧠
9. An air bubble is trapped under a leaf floating on the water surface of a lake. The volume of the air bubble is 3.6 cm³ when the temperature is 20°C.
- What is the volume of the air bubble when the water temperature rises to 38°C? 🧠
 - State three assumptions that need to be made in your calculations in 9(a). 🧠
10. Figure 2 shows ice cubes being heated by a 500 W immersion heater for 80 seconds. The melted ice cubes are collected in a beaker.
- [Specific latent heat of fusion of ice = $3.34 \times 10^5 \text{ J kg}^{-1}$]

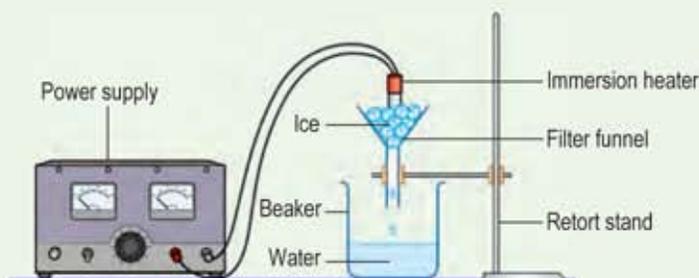


Figure 2

- What is meant by specific latent heat of fusion?
 - Why does the temperature remain unchanged when the ice cubes are changing into liquid?
 - Calculate:
 - energy absorbed by the ice cubes.
 - mass of melted ice cubes.
 - What assumptions are made in your calculations in 10(c)? 🧠
11. An electric kettle is filled with 500 g of water at 30°C. The power of the heating element of the kettle is 0.8 kW. Assume that all heat from the heating element is transferred to the water.
- [Specific heat capacity of water = $4\,200 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$]
- Calculate:
 - heat energy needed to increase the temperature of the water to 100°C. 🧠
 - time taken by the kettle to heat water to a temperature of 100°C. 🧠
 - Why is the handle of the kettle made of plastic? 🧠
 - Why is the heating element of the kettle made of metal? 🧠
 - The heating element of the kettle is located at the base of the kettle. Explain why. 🧠

3. Block *A* has a high specific heat capacity and block *B* has a low specific heat capacity. If both blocks have the same mass,
- which block needs more energy to raise its temperature by 10°C ?
 - which block heats up more quickly if supplied with the same amount of heat? Explain your answer.

4. (a) Define specific latent heat.
- (b) The mass of a melting ice cube reduces by 0.68 kg . What is the amount of heat absorbed from the surrounding by the ice cube? 🧠
 [Specific latent heat of fusion of ice = $3.34 \times 10^5\text{ J kg}^{-1}$]

5. (a) What is meant by specific latent heat of vaporisation?
- (b) Figure 1 shows the graph of mass of water, m against time, t when water in a beaker is heated by a $1\,800\text{ W}$ electric heater. At time $t = 360\text{ s}$, the water starts to boil.

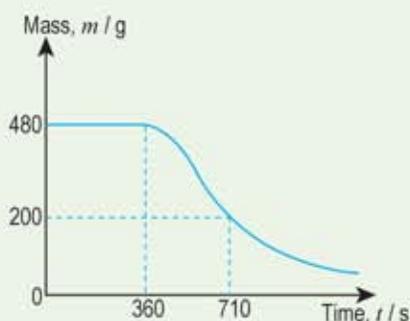


Figure 1

Calculate:

- mass of water that becomes steam from $t = 360\text{ s}$ until $t = 710\text{ s}$. 🧠
 - specific latent heat of vaporisation of water. 🧠
6. A gold ring of mass 5.5 g experiences a rise in temperature from 36°C to 39°C . How much heat energy is absorbed by the ring? 🧠
 [Specific heat capacity of gold = $300\text{ J kg}^{-1}\text{ }^{\circ}\text{C}^{-1}$]

7. Photograph 2 shows the power rating label of an electric kettle.

- What is the maximum power of this electric kettle?
- Calculate the time taken by this kettle to change 0.5 kg of boiling water at 100°C into steam at 100°C when the kettle operates at maximum power. 🧠
 [Specific latent heat of vaporisation of water = $2.26 \times 10^6\text{ J kg}^{-1}$]



Photograph 2

- What assumptions are made in your calculations in 7(b)? 🧠

12. A substance has a mass of 250 g. The substance loses 5 625 J of heat when cooled. There is a 25°C drop in temperature.

- (a) Calculate the specific heat capacity of the substance. Identify the substance based on Table 4.2 on page 128. 🧠
- (b) Explain the use of the substance based on its specific heat capacity. 🧠

13. Photograph 3 shows a bamboo steamer. Amin receives an order from a supermarket to supply 400 steamed buns per day. Suggest and explain the design of the steamer needed. The steamer should be durable, and able to prepare a large quantity of steamed buns in a short time. 🧠



Photograph 3



Enrichment Corner

14. Khairi orders a cup of coffee in a restaurant. He finds that the coffee is too hot. Photograph 4 shows two suggested ways to cool the coffee.



Method A



Method B

Photograph 4

- (a) Discuss the suitability of methods A and B to cool the coffee in the cup. 🧠
- (b) State your choice. Give reasons for your choice. 🧠