$$
\begin{aligned}
(752 \times 60)\ J &= 4{\cdot}51 \times 10^4\ J \\
Q &= mc\Delta T \\
4{\cdot}51 \times 10^4 &= (5{\cdot}0 \times 10^{-1})\,(4{\cdot}18 \times 10^3)\,(T_2 - 25{\cdot}0) \\
4{\cdot}51 \times 10^4 &= 2{\cdot}09 \times 10^3 T_2 - 5{\cdot}22 \times 10^4 \\
2{\cdot}09 \times 10^3 T_2 &= 4{\cdot}51 \times 10^4 + 5{\cdot}22 \times 10^4 \\
&= 9{\cdot}73 \times 10^4 \\
\therefore T_2 &= \frac{9{\cdot}73 \times 10^4}{2{\cdot}09 \times 10^3} \\
&= 47\ ^\circ C
\end{aligned}
$$

***The final temperature of the water is 47 °C.***

Use the following data in the problems in this chapter:

Specific heat of water $c_w = 4{\cdot}18 \times 10^3$ J kg$^{-1}$ K$^{-1}$

Latent heat of fusion of water = $3{\cdot}34 \times 10^5$ J kg$^{-1}$

Latent heat of vaporisation of water = $2{\cdot}25 \times 10^6$ J kg$^{-1}$

## Set 23

**1** How much heat energy is required to raise the temperature of $1{\cdot}53 \times 10^2$ kg of water from 15·0 °C to 35·0 °C?

**2** How many joules of heat energy are lost if 865 g of aluminium (specific heat $8{\cdot}80 \times 10^2$ J kg$^{-1}$ K$^{-1}$) is cooled from 120 °C to 55 °C?

**3** $5{\cdot}85 \times 10^2$ kg of pyrex glass (specific heat $8{\cdot}37 \times 10^2$ J kg$^{-1}$ K$^{-1}$) loses $8{\cdot}65 \times 10^6$ J of heat. If the temperature of the glass is 95·8 °C before cooling, what is its final temperature?

**4** Calculate the specific heat of a piece of steel if $5{\cdot}53 \times 10^7$ J of heat is required to heat a 286 kg mass of the steel from 22 °C to 452 °C.

**5** By how much will the temperature of a 2·75 kg mass of lead change if $2{\cdot}84 \times 10^4$ J of heat is supplied it? (Specific heat of lead is $1{\cdot}30 \times 10^2$ J kg$^{-1}$ K$^{-1}$.)

**6** What mass of water can be raised in temperature from 15·0 °C to its boiling point when $2{\cdot}93 \times 10^6$ J of heat is supplied?

**7** A glass beaker of mass 215 g contains 145 g of water at 18·5 °C. If the specific heat of glass is $8{\cdot}40 \times 10^2$ J kg$^{-1}$ K$^{-1}$, how much heat energy would need to be supplied to raise the temperature of the glass and water to 98·5 °C?

**8** A hot water bottle contains 3·0 L of water at 45 °C. At what rate (in joules per second) is the water losing heat if it cools to 38 °C over an 8·0 h period?

**9** A stainless steel kettle of mass $5{\cdot}25 \times 10^{-1}$ kg contains $1{\cdot}55 \times 10^{-1}$ kg of water. If 65·0% of the electrical heat supplied is converted to heat, how much electrical energy is required to raise the temperature of the kettle and water from 12·0 °C to 96·0 °C? The specific heat of stainless steel is $4{\cdot}45 \times 10^2$ J kg$^{-1}$ K$^{-1}$.

3 515 g of water at a temperature of 65·5 °C is poured into a 655 g glass container (specific heat $8{\cdot}42 \times 10^2$ J kg$^{-1}$ K$^{-1}$). If the initial temperature of the glass is 20·0 °C, find the final temperature.

4 What mass of ice at its melting point would be needed to lower the temperature of 0·75 kg of water, initially at 95 °C, to 3·5 °C?

5 A copper calorimeter (specific heat of $3{\cdot}90 \times 10^2$ J kg$^{-1}$ K$^{-1}$) has a mass of 155 g and contains 95·5 g of water all at 62·4 °C. What mass of ice is needed to cool the calorimeter and water down to 16·5 °C?

6 What mass of dry steam at $1{\cdot}00 \times 10^2$ °C needs to be blown over a 1·50 kg lump of ice at 0·0 °C to convert it to water at 21·5 °C?

7 A 3·55 kg sample of an alloy is heated to 295 °C and plunged into an aluminium vessel containing 10·0 L of water. The initial temperature of the vessel and water is 19·0 °C, the mass of the aluminium vessel is 2·10 kg and the specific heat of aluminium is $9{\cdot}00 \times 10^2$ J kg$^{-1}$ K$^{-1}$. If the final temperature is 28·5 °C, find the specific heat of the alloy.

8 35·5 g of metal tacks at 85·0 °C are dropped into a copper calorimeter of mass 60·0 g containing 54·0 g of water at 15·5 °C. If the specific heat of copper is $3{\cdot}90 \times 10^2$ J kg$^{-1}$ K$^{-1}$ and the final temperature is 19·5 °C, find the specific heat of the metal tacks.

9 A thermally insulated glass of mass 435 g contains 125 g of water at a temperature of 45·4 °C. When a lump of ice initially at −2·50 °C is allowed to melt in the water, the final temperature is 4·14 °C. Given that the specific heats of ice and glass are $2{\cdot}10 \times 10^3$ J kg$^{-1}$ K$^{-1}$ and $8{\cdot}40 \times 10^2$ J kg$^{-1}$ K$^{-1}$, find the mass of ice added.

10 55·0 g of water at 60·0 °C is poured into a copper calorimeter containing 105 g of water at 12·0 °C. If the highest temperature reached after mixing is 24·5 °C, and the specific heat of copper is $3{\cdot}90 \times 10^2$ J kg$^{-1}$ K$^{-1}$, find the mass of the copper calorimeter.

11 A piece of copper of mass 0·50 kg is heated to 610 °C and then dropped into a copper calorimeter of mass 0·11 kg containing 0·13 kg of water at 21 °C. If the specific heat of copper is 390 J kg$^{-1}$ K$^{-1}$, calculate the mass of water lost by boiling.

12 A 5·45 kg steel container (specific heat $4{\cdot}50 \times 10^2$ J kg$^{-1}$ K$^{-1}$) contains 12·0 kg of water at 22·0 °C. When 2·65 kg of molten alloy (latent heat of fusion $2{\cdot}50 \times 10^4$ J kg$^{-1}$ K$^{-1}$) at its melting point of 327 °C is poured into the water the final temperature reached is 27·8 °C. Find the specific heat of the alloy.

### *Example 3*

*How much heat energy is required to melt 0·25 kg of ice?*

$m = 0{\cdot}25$ kg
$L_f = 3{\cdot}34 \times 10^5$ J kg$^{-1}$

$$Q = mL$$
$$= (0{\cdot}25)\,(3{\cdot}34 \times 10^5)\,\text{J}$$
$$= 8{\cdot}4 \times 10^4\ \text{J}$$

***The heat required to melt the ice is $8{\cdot}4 \times 10^4$ J.***

### *Example 4*

*What mass of water initially at 15·5 °C can be converted to steam if $8{\cdot}65 \times 10^6$ J of heat energy is supplied?*

$Q = 8{\cdot}65 \times 10^6$ J
$L_v = 2{\cdot}25 \times 10^6$ J kg$^{-1}$
$C_w = 4{\cdot}18 \times 10^3$ J kg$^{-1}$ K$^{-1}$
$T = 15{\cdot}5$ °C

*Heat required to bring the water to the boil*

$$Q = mc\Delta t$$
$$= m(4{\cdot}18 \times 10^3)\,(100 - 15{\cdot}5)$$
$$= (3{\cdot}53 \times 10^5 \times m)\ \text{J}$$

*Heat required to change the water to steam*

$$Q = mL$$
$$= (2{\cdot}25 \times 10^6 \times m)\ \text{J}$$

$\therefore$ *total heat required*

$$= 3{\cdot}53 \times 10^5\,m + 2{\cdot}25 \times 10^6\,m$$
$$= 2{\cdot}60 \times 10^6 \times m$$

*Heat supplied* $= 8{\cdot}65 \times 10^6$ J

$$\therefore 2{\cdot}60 \times 10^6\,m = 8{\cdot}65 \times 10^6$$
$$m = \frac{8{\cdot}65 \times 10^6}{2{\cdot}60 \times 10^6}$$
$$= 3{\cdot}33\ \text{kg}$$

***The mass of water converted to steam is 3·33 kg.***

## Set 24

1. How much heat energy is required to melt 28·6 kg of ice at 0 °C?
2. How much heat energy is released when 423 g of steam at 100 °C is condensed to water at the same temperature?
3. If $1{\cdot}85 \times 10^4$ of heat is released when $3{\cdot}85 \times 10^{-3}$ kg of tungsten is condensed at its boiling point, what is the latent heat of vaporisation of tungsten?
4. What mass of ethanol can be solidified by the removal of $9{\cdot}53 \times 10^4$ J of heat energy at its melting point? The latent heat of fusion of ethanol is $1{\cdot}05 \times 10^5$ J kg$^{-1}$.
5. How much heat energy is required to heat 1·15 kg of ice at 0·0 °C to water at 21·5 °C?

6 How much heat energy is released when 552 g of liquid lead at its melting point of 327·0 °C is cooled at 21·5 °C? The specific heat of lead is $1{\cdot}29 \times 10^2$ J kg$^{-1}$ K$^{-1}$ and the latent heat of fusion of lead is $2{\cdot}51 \times 10^4$ J kg$^{-1}$.

7 How much heat energy is required to convert 86·3 g of ice at −5·0 °C to steam at its boiling point? The specific heat of ice is $2{\cdot}10 \times 10^3$ J kg$^{-1}$ K$^{-1}$

8 An immersion heater can supply heat at the rate of $4{\cdot}80 \times 10^2$ J s$^{-1}$. How long will it take to boil away $1{\cdot}25 \times 10^{-1}$ kg of water at 26·5 °C?

9 A 2·00 kg block of ice at 0 °C is just melted by supplying heat at a uniform rate for 15 min. At what rate, in joules per second, is heat being supplied?

10 At what rate is a refrigerator absorbing heat if 2·15 kg of water at 21·5 °C is just frozen in 2·00 h?

---

*Answers*

| | |
|---|---|
| *1* $9{\cdot}55 \times 10^6$ *J* | *2* $9{\cdot}52 \times 10^5$ *J* |
| *3* $4{\cdot}80 \times 10^6$ *J kg*$^{-1}$ | *4* *0·908 kg* |
| *5* $4{\cdot}87 \times 10^5$ *J* | *6* $3{\cdot}56 \times 10^4$ *J* |
| *7* $2{\cdot}6 \times 10^5$ *J* | *8* $6{\cdot}66 \times 10^2$ *s* |
| *9* $7{\cdot}4 \times 10^2$ *J s*$^{-1}$ | *10* $1{\cdot}27 \times 10^2$ *J s*$^{-1}$ |

---

## Methods of mixtures

When two substances at different temperatures are mixed one will gain heat and the other lose heat until thermal equilibrium is reached. If no heat is lost to the surroundings, then the heat lost by one object will be equal to the heat gained by the other object.

Total heat gained = Total heat lost

*Example 5*

*A lump of copper of mass 2·75 kg and temperature 122 °C is dropped into 5·25 kg of water at 12·0 °C. If the specific heat of copper is $3{\cdot}90 \times 10^2$ J kg$^{-1}$ K$^{-1}$, what is the final temperature?*

$m_{Cu} = 2{\cdot}75$ kg

$c_{Cu} = 3{\cdot}90 \times 10^2$ J kg$^{-1}$ K$^{-1}$

$\triangle T_{Cu} = (122 - T)$ K

$m_w = 5{\cdot}25$ kg

$c_w = 4{\cdot}18 \times 10^3$ J kg$^{-1}$ K$^{-1}$

$\triangle T_w = (T - 12)$ K

$$\left[\begin{array}{l}\text{Heat lost}\\ \text{by copper}\end{array}\right] = mc\triangle T = (2{\cdot}75)\,(3{\cdot}90 \times 10^2)\,(122 - T)$$

$$\left[\begin{array}{l}\text{Heat gained}\\ \text{by water}\end{array}\right] = mc\triangle T = (5{\cdot}25)\,(4{\cdot}18 \times 10^3)\,(T - 12)$$

*Assuming no heat losses*

$$
\begin{aligned}
\text{Heat lost by copper} &= \text{Heat gained by water} \\
(2{\cdot}75)\,(3{\cdot}90 \times 10^2)\,(122 - T) &= (5{\cdot}25)\,(4{\cdot}18 \times 10^3)\,(T - 12) \\
1{\cdot}31 \times 10^5 - 1{\cdot}07 \times 10^3\,T &= 2{\cdot}19 \times 10^4\,T - 2{\cdot}63 \times 10^5 \\
2{\cdot}30 \times 10^4\,T &= 3{\cdot}94 \times 10^5 \\
T &= \frac{3{\cdot}94 \times 10^5}{2{\cdot}30 \times 10^4} \\
&= 17{\cdot}1\ ^\circ\text{C}
\end{aligned}
$$

***The final temperature of the water is 17·1 °C.***

## Example 6

*$1{\cdot}63 \times 10^{-2}$ kg of ice at its melting point is added to a copper calorimeter of mass $3{\cdot}51 \times 10^{-1}$ kg containing $1{\cdot}11 \times 10^{-1}$ kg of water. If the calorimeter and water are initially at 28·5 °C, what will be the resulting temperature of the mixture?*

$m_i = 1{\cdot}63 \times 10^{-2}$ kg
$L_i = 3{\cdot}34 \times 10^5\ \text{J kg}^{-1}$
$\triangle T_i = (T - 0)$ K
$m_{Cu} = 3{\cdot}51 \times 10^{-1}$ kg
$c_{Cu} = 3{\cdot}90 \times 10^2\ \text{J kg}^{-1}\,\text{K}^{-1}$
$\triangle T_{Cu} = (28{\cdot}5 - T)$ K
$m_w = 1{\cdot}11 \times 10^{-1}$ kg
$c_w = 4{\cdot}18 \times 10^3\ \text{J kg}^{-1}\,\text{K}^{-1}$
$\triangle T_w = (28{\cdot}5 - T)$ K

$$
\begin{bmatrix}\text{Total}\\ \text{heat}\\ \text{gained}\end{bmatrix} = \begin{bmatrix}\text{Heat gained}\\ \text{by ice}\\ \text{melting}\end{bmatrix} + \begin{bmatrix}\text{Heat gained by the}\\ \text{melting ice heated}\\ \text{to the final temp.}\end{bmatrix}
$$

$$
Q_{gained} = m_i L_i + m_i c_w \triangle T_i
$$

$$
\begin{bmatrix}\text{Total}\\ \text{heat}\\ \text{lost}\end{bmatrix} = \begin{bmatrix}\text{Heat lost by}\\ \text{the copper}\\ \text{calorimeter}\end{bmatrix} + \begin{bmatrix}\text{Heat lost by the}\\ \text{water in the}\\ \text{calorimeter cooling}\end{bmatrix}
$$

$$
Q_{lost} = m_{Cu} c_{Cu} \triangle T_{Cu} + m_w c_w \triangle T_w
$$

$$
\begin{aligned}
\text{Total heat gained} &= \text{Total heat lost} \\
m_i L_i + m_i c_w \triangle T_i &= m_{Cu} c_{Cu} \triangle T_{Cu} + m_w c_w \triangle T_w
\end{aligned}
$$

$$
\begin{bmatrix}(1{\cdot}63 \times 10^{-2})\,(3{\cdot}34 \times 10^5)\\ + (1{\cdot}63 \times 10^{-2})\,(4{\cdot}18 \times 10^3)\,(T - 0)\end{bmatrix} = \begin{bmatrix}(3{\cdot}51 \times 10^{-1})\,(3{\cdot}90 \times 10^2)\,(28{\cdot}5 - T)\\ + (1{\cdot}11 \times 10^{-1})\,(4{\cdot}18 \times 10^3)\,(28{\cdot}5 - T)\end{bmatrix}
$$

$$
\begin{aligned}
5{\cdot}444 \times 10^3 + (6{\cdot}813 \times 10^2)\,(T) &= (1{\cdot}369 \times 10^2 + 4{\cdot}640 \times 10^2)\,(28{\cdot}5 - T) \\
5{\cdot}444 \times 10^3 + (6{\cdot}813 \times 10^2)\,(T) &= 6{\cdot}009 \times 10^2\,(28{\cdot}5 - T) \\
5444 + 68{\cdot}13\,T &= 600{\cdot}9\,(28{\cdot}5 - T) \\
5444 + 68{\cdot}13\,T &= 17\,125{\cdot}6 - 600{\cdot}9\,T \\
669{\cdot}0\,T &= 11\,681{\cdot}65 \\
T &= 17{\cdot}4\ ^\circ\text{C}
\end{aligned}
$$

***The final temperature is 17·4 °C.***

## Set 25

1 If 0·20 kg of water at 85·5 °C is mixed with 0·54 kg of water at 15·5 °C, what will be the resulting temperature of the mixture?

2 What mass of water at a temperature of 2·5 °C is added to 15 g of ethanol (specific heat $2{\cdot}40 \times 10^3\ \text{J kg}^{-1}\ \text{K}^{-1}$) at 18 °C if the mixture reaches a final temperature of 6·0 °C?