Week 30

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Physics Name: ____________ Score: ______

1. Heat (thermal energy) naturally flows from:
   - ☐ higher to lower temperature
   - ☐ lower to higher temperature
   - ☐ bigger to smaller object
   - ☐ lighter to heavier object

2. Select **all** the properties that can be used to measure temperature.
   - ☐ expansion of a liquid
   - ☐ resistance of a metal
   - ☐ e.m.f. of a thermocouple
   - ☐ the colour of the glass case

   Tick every correct option.

3. How much energy raises 2.0 kg of water by 10 K? (Use $c = 4200\ \frac{\text{J}}{\text{kg}\cdot\text{K}}$.)

   ____________ J

4. At thermal equilibrium there is no net flow of energy between two bodies.

   ☐ True ☐ False

5. Absolute zero (0 K) is:
   - ☐ the lowest possible temperature
   - ☐ the freezing point of water
   - ☐ room temperature
   - ☐ the boiling point of water

6. Water has a high specific heat capacity compared with most metals.

   ☐ True ☐ False

7. Two objects in thermal equilibrium are at the same ______.

   ____

8. What is 27 °C in kelvin?

   ____________ K

9. While a solid is melting, its temperature:

- ☐ stays constant
- ☐ rises steadily
- ☐ falls
- ☐ doubles

10. Temperature tells you:
    - ☐ which way heat will flow
    - ☐ the total thermal energy stored
    - ☐ the mass of the object
    - ☐ the volume of the object

A-Level Physics

1. **higher to lower temperature**

   Energy always flows down the temperature difference, from hot to cold, until they are equal.

2. **expansion of a liquid; resistance of a metal; e.m.f. of a thermocouple**

   Any property that changes repeatably with temperature works. The fixed colour of the case does not.

3. **84000 J**

   $Q = mc\Delta T = 2.0 \times 4200 \times 10 = 84000$ J.

4. **True**

   Equal temperatures mean no net flow — particles still exchange energy, but with no overall transfer.

5. **the lowest possible temperature**

   At 0 K a system has its least possible internal energy; nothing can be made colder.

6. **True**

   Water ~4200 vs aluminium ~900, copper ~385 J/(kg · K) — water needs much more energy per kelvin.

7. **temperature**

   Same temperature is exactly the condition for thermal equilibrium.

8. **300 K**

   $T/\text{K} = \theta/°\text{C} + 273 = 27 + 273 = 300$ K.

9. **stays constant**

   During a state change the energy breaks bonds rather than raising temperature, so it stays constant.

10. **which way heat will flow**

    Temperature decides the direction of heat flow; the amount of energy also depends on mass and material.

14.1 Thermal equilibrium

Name: ____________ Class: ________ Date: __________ **Total: 19 marks**

KEY WORDS temperature 温度 • thermal equilibrium 热平衡 • thermal energy 热能 • heat 热量 • energy 能量

Objective

Build the skills to answer exam questions on **thermal equilibrium**.

You must be able to:

- state that thermal energy flows from **higher** to **lower** temperature
- explain **thermal equilibrium** and that temperature is not the same as thermal energy

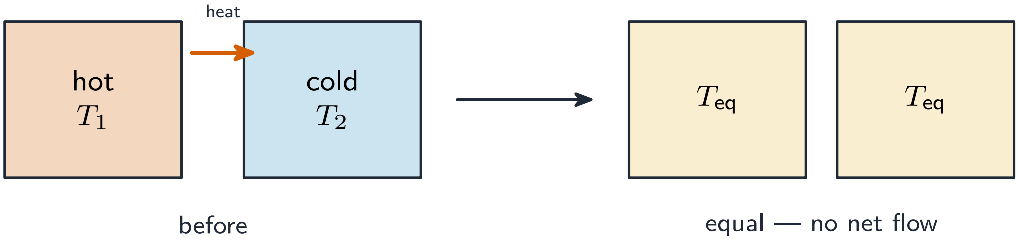
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Heat flow and equilibrium

Thermal energy flows from **hot to cold**. When two bodies touch, energy moves until their temperatures are equal — **thermal equilibrium**, with **no net** energy flow:

energy flows hot → cold until T equal



Heat flows until thermal equilibrium

Temperature decides the **direction** of flow — it is **not** how much thermal energy a body holds. A cup of boiling water holds far less energy than a warm swimming pool, but heat still flows **from** the cup **to** a cooler object.

2 Practice

Now apply the methods above.

2.1 State the direction in which thermal energy flows. [1]

2.2 State what is meant by **thermal equilibrium**. [2]

2.3 Two objects at the **same temperature** are in contact. State the **net** flow of energy between them. [1]

3 Exam-style questions

3.1 State what is meant by two objects being in **thermal equilibrium**. [2]

3.2 Explain why a small cup of boiling water (100 °C) may hold **less** thermal energy than a swimming pool at 25 °C. [2]

3.3 Thermal energy flows from object A to object B. This tells you that: [1]

- **A** A is at a higher temperature than B
- **B** B is at a higher temperature than A
- **C** A and B are at the same temperature
- **D** A contains more thermal energy than B

3.4 Two blocks, P and Q, are made of the same metal. P has mass 0.50 kg and is at 80 °C; Q has mass 1.5 kg and is at 20 °C. They are placed in contact inside a perfectly insulating box.

(a) **State**, with a reason, the direction of the net flow of thermal energy at the moment they touch. [2]

(b) **Explain**, in terms of the molecules, what “thermal equilibrium” means for these two blocks, and what is true of their temperatures when it is reached. [3]

(c) The specific heat capacity of the metal is 390 $\text{J kg}^{-1}\,\text{K}^{-1}$. **Determine** the final temperature of the two blocks. [3]

(d) **State and explain** whether the two blocks hold equal amounts of internal energy once they are in thermal equilibrium. [2]

Solutions

2.1 From a region of **higher temperature** to a region of **lower temperature**.

2.2 Two bodies are at the **same temperature**, so there is **no net flow** of thermal energy between them.

2.3 **Zero** (no net flow).

3.1 They are at the **same temperature**, so there is **no net transfer** of thermal energy between them.

3.2 Temperature shows the **direction** of heat flow, not the amount of energy stored; the pool has a far greater **mass**, so it can hold more total thermal energy despite its lower temperature.

3.3 **A** — A is at a higher temperature than B.

3.4 (a) From **P to Q**, because P is at the higher **temperature**, and thermal energy always flows from the hotter body to the colder one.
(b) Their molecules collide at the boundary and transfer energy, and on average energy passes from the block whose molecules have the greater mean kinetic energy. At thermal equilibrium there is **no net** flow of energy either way, and the two blocks are at the **same temperature**.
(c) Energy lost by P = energy gained by Q, so $0.50 \times 390 \times (80 - \theta) = 1.5 \times 390 \times (\theta - 20)$. The specific heat capacity cancels: $0.50(80 - \theta) = 1.5(\theta - 20)$, so $40 - 0.5\theta = 1.5\theta - 30$ and $\theta = \dfrac{70}{2.0} = 35$ °C.
(d) **No**. They are at the same temperature, so their molecules have the same **mean** kinetic energy, but Q has three times the mass and therefore three times as many molecules, so it holds about three times the internal energy.

2 **(a)** State what is meant by two objects being in thermal equilibrium.

....

....

.... [2]

(b) A mass X of ice at 0 °C is placed in a beaker containing a mass M of water at Celsius temperature t. The beaker is perfectly insulated and has negligible heat capacity. After some time, the ice that was added reaches thermal equilibrium with the original water in the beaker.

The specific latent heat of fusion of water is L. The specific heat capacity of water is c. The final Celsius temperature of the system is θ.

Give expressions, in terms of some or all of X, M, t, θ, L and c, for the thermal energy:

(i) E_1, gained by the ice as it melts to become water at 0 °C

E_1 = ... [1]

(ii) E_2, lost by the water as its Celsius temperature decreases from t to θ

E_2 = ... [1]

(iii) E_3, gained by the melted ice as its Celsius temperature increases from 0 °C to θ.

E_3 = ... [1]

(c) Use your answers in **(b)** to show that the final Celsius temperature θ of the system is given by

$$\theta = \frac{Mct - XL}{c(M + X)}.$$

[2]

[Total: 7]

3 **(a)** Two metal cuboids P and Q are in thermal contact with each other.

(i) P and Q are in thermal equilibrium.

State what is meant by the term thermal equilibrium.

....

....

.... [2]

(ii) Data for P and Q are given in Table 3.1.

Table 3.1

	P	Q
specific heat capacity / $J\,kg^{-1}\,K^{-1}$	390	910
mass / kg	0.54	0.37

P and Q are initially both at the same temperature.

P is supplied with 24 kJ of thermal energy. After some time, P and Q are once again both at the same temperature as each other.

P and Q are perfectly insulated from the surroundings.

Determine the change in temperature ΔT of Q.

ΔT = ... K [3]

(b) Nitrogen may be assumed to be an ideal gas. A fixed amount of nitrogen gas is contained at a constant pressure of 1.6×10^5 Pa.

The variation of the volume V of the gas with the temperature θ of the gas is shown in Fig. 3.1.

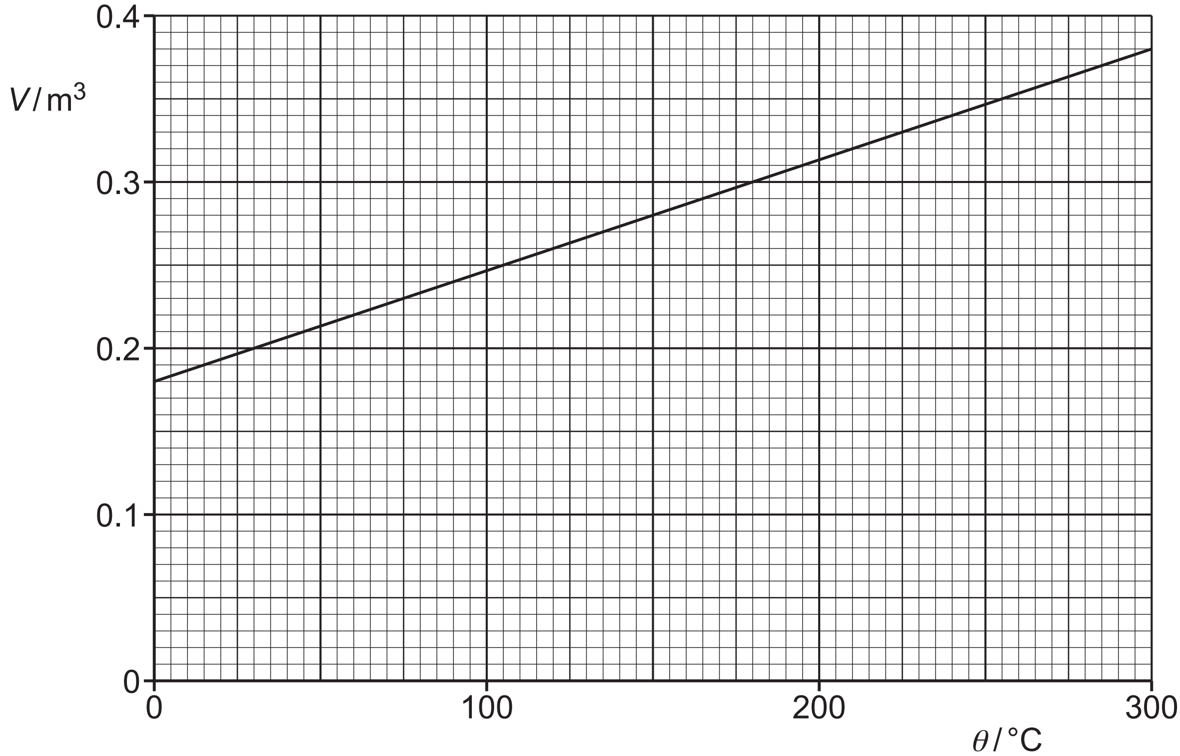


Fig. 3.1

(i) The temperature of the nitrogen gas is increased from 0 °C to 210 °C. Determine the work done on the gas.

work done = ... J [3]

(ii) Determine the number N of molecules of nitrogen gas.

N = ... [2]

(iii) The mass of a nitrogen molecule is 4.7×10^{-26} kg.

Calculate the root-mean-square (r.m.s.) speed of a nitrogen molecule at 210 °C.

r.m.s. speed = ... m s^{-1} [2]

[Total: 12]

14.2 Temperature scales

Name: ____________ Class: ________ Date: __________ **Total: 21 marks**

KEY WORDS absolute zero 绝对零度 • celsius 摄氏度 • kelvin 开尔文 • thermocouple 热电偶 • temperature 温度

Objective

Build the skills to answer exam questions on **temperature scales** — thermometry, kelvin/Celsius, and absolute zero.

You must be able to:

- name **physical properties** used to measure temperature
- convert between **kelvin** and **Celsius** ($T/\mathrm{K} = \theta/°\mathrm{C} + 273.15$)
- explain **absolute zero** and the thermodynamic scale

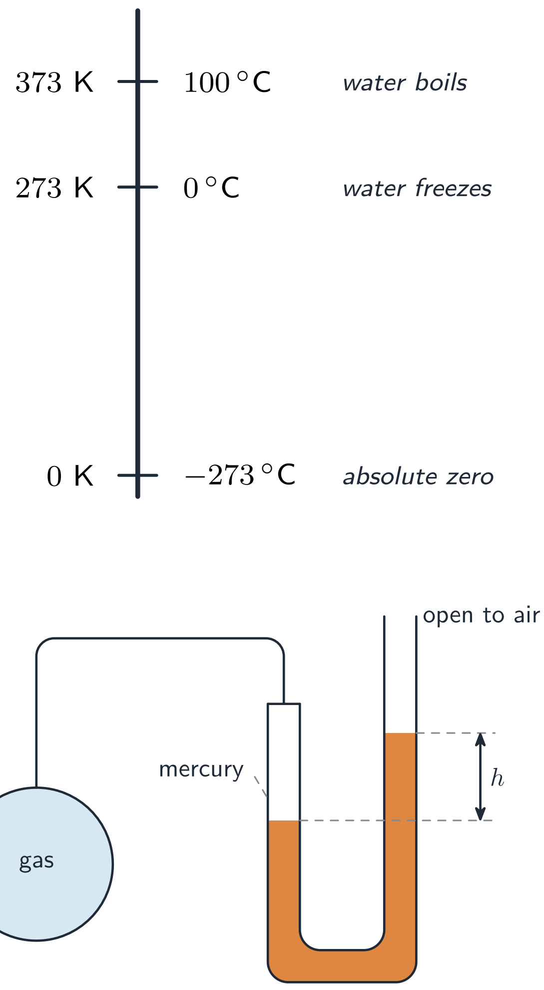
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ **Thermometers**

Any **physical property** that changes repeatably with temperature can make a thermometer: density of a liquid, volume of a gas, **resistance** of a metal, or the **e.m.f. of a thermocouple**.

■ **The two scales**



A gas thermometer and absolute zero

$$T/\mathrm{K} = \theta/^\circ\mathrm{C} + 273.15.$$

The **thermodynamic** scale does **not** depend on any one substance. The lowest possible temperature is **absolute zero** (0 K = −273.15 °C), where a system has its least internal energy.

2 Practice

Now apply the methods above.

2.1 Convert 27 °C to **kelvin**. [1]

2.2 Convert 200 K to **degrees Celsius**. [1]

2.3 State the value of **absolute zero** in °C. [1]

2.4 Name **two** physical properties used in thermometers. [2]

3 Exam-style questions

3.1 A temperature of 100 °C in kelvin is: [1]

- **A** 173 K
- **B** 373 K
- **C** 273 K
- **D** 100 K

3.2 State what is meant by **absolute zero**. [2]

3.3 Convert 310 K to **degrees Celsius**. [1]

3.4 Explain why the **thermodynamic** (kelvin) scale is preferred over a scale based on a single physical property. [2]

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is 1.38 ×

10^{-23} J K^{-1}, the Avogadro constant is 6.02×10^{23} mol^{-1} and 1 u $= 1.66 \times 10^{-27}$ kg.

(a) **State** the temperature of absolute zero on

(i) the Celsius scale, [1]

(ii) the thermodynamic scale, with its unit. [1]

(b) For this sample, a graph of pV against thermodynamic temperature T is a **straight line through the origin**. **State** what this tells you about the gas. [1]

(c) At one point on that line, $pV = 340$ J and $T = 640$ K. **Determine** the number N of molecules in the sample. [2]

(d) **Determine** the amount of gas, in moles. [1]

(e) At that temperature the root-mean-square speed of the molecules is 1400 m s^{-1}. **Determine** the mass of one molecule, in u. [4]

Solutions

2.1 $T = 27 + 273 = 300$ K.

2.2 $\theta = 200 - 273 = -73$ °C.

2.3 -273 °C (-273.15).

2.4 Any two: density of a liquid; volume of a gas; resistance of a metal; e.m.f. of a thermocouple.

3.1 **B** — 373 K.

3.2 The **lowest possible temperature**, at which a system has its **minimum internal energy** (least particle motion).

3.3 $\theta = 310 - 273 = 37$ °C.

3.4 A property-based scale depends on **how that property changes** (it may not be linear), so different thermometers can disagree; the thermodynamic scale is defined independently of any substance, so it is consistent.

3.5 (a)(i) -273.15 °C.
(a)(ii) 0 K — the unit is required.
(b) The gas behaves as an **ideal gas**: $pV \propto T$ with no intercept, which is what $pV = NkT$ predicts.
(c) $pV = NkT$, so $N = \dfrac{340}{1.38 \times 10^{-23} \times 640} = 3.8 \times 10^{22}$.
(d) $n = \dfrac{N}{N_A} = \dfrac{3.8 \times 10^{22}}{6.02 \times 10^{23}} = 0.064$ mol.
(e) For an ideal gas $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$, so $m = \dfrac{3kT}{\langle c^2\rangle} = \dfrac{3 \times 1.38 \times 10^{-23} \times 640}{(1400)^2} = 1.35 \times 10^{-26}$ kg; dividing by 1.66×10^{-27} gives 8.1 u.

4 **(a)** State the value of absolute zero on:

(i) the Celsius temperature scale

temperature = ... °C [1]

(ii) the thermodynamic temperature scale. Give a unit with your answer.

temperature = ... unit .... [1]

(b) A sample contains a fixed amount of gas. The gas has pressure p, volume V and thermodynamic temperature T.

Fig. 4.1 shows the variation of pV with kT for the sample, where k is the Boltzmann constant.

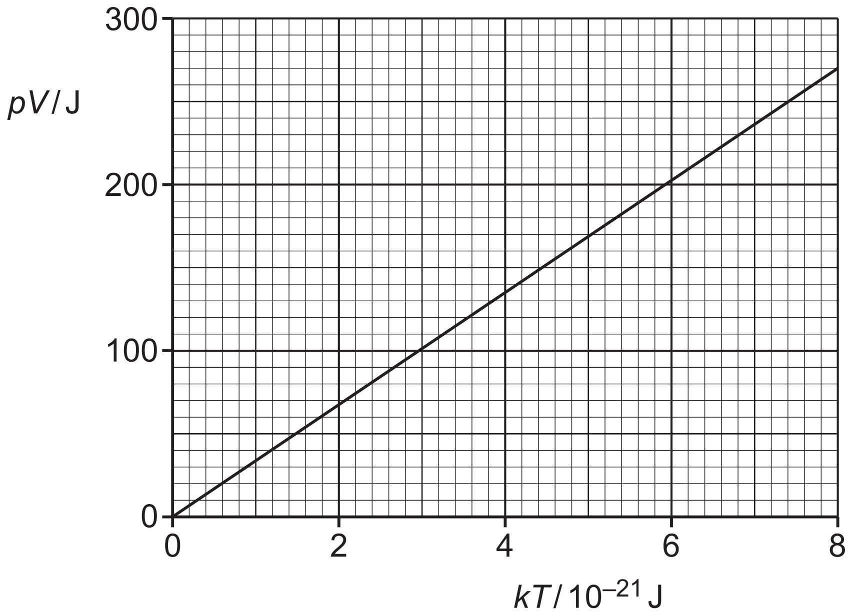


Fig. 4.1

(i) State what is indicated about the nature of the gas from the variation shown in Fig. 4.1.

.... [1]

(ii) Determine the number N of molecules of the gas in the sample.

N = ... [2]

(iii) Use your answer in **(b)(ii)** to determine the amount *n* of gas in the sample.

n = ... mol [1]

(c) The root-mean-square (r.m.s.) speed of the molecules of the gas is $1900\,\mathrm{m\,s^{-1}}$ when pV is equal to 270 J.

Determine the mass, in u, of one molecule of the gas, where u is the unified atomic mass unit.

mass = ... u [4]

[Total: 10]

14.3 Specific heat capacity and specific latent heat

Name: ______________ Class: __________ Date: ____________ **Total: 28 marks**

KEY WORDS specific heat capacity 比热容 • latent heat 潜热 • specific latent heat 比潜热 • fusion 熔化 • vaporisation 汽化

Objective

Build the skills to answer exam questions on **specific heat capacity** and **specific latent heat**.

You must be able to:

- use $Q = mc\Delta T$ and $Q = mL$ (fusion vs vaporisation)
- measure c **electrically** ($Q = VIt$) and by the **method of mixtures**
- read a **heating curve**; explain why $L_{\text{vap}} > L_{\text{fusion}}$

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Specific heat capacity

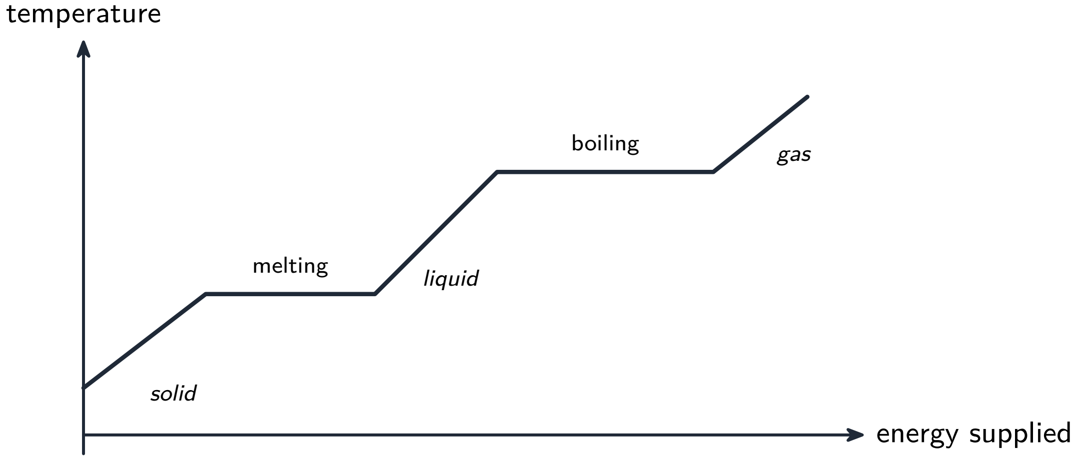
The energy to raise unit mass by one kelvin:

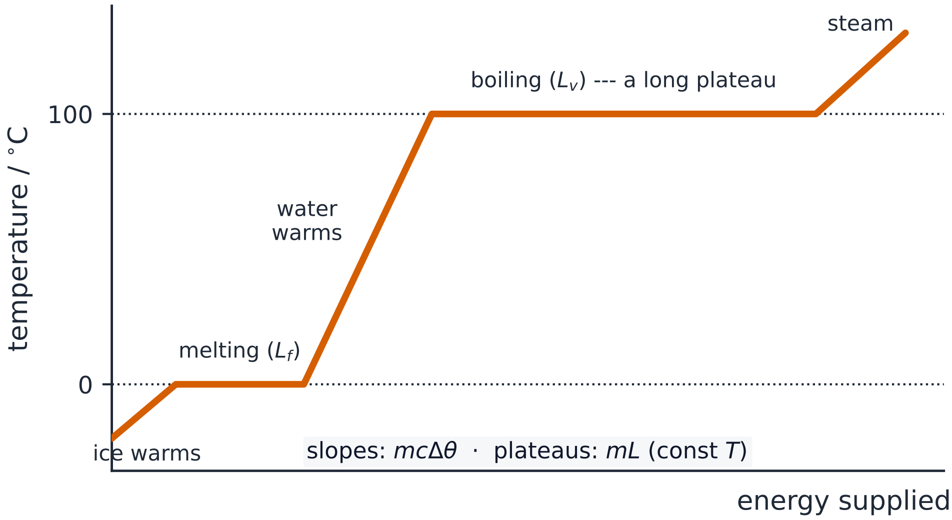
$$c = \frac{Q}{m\Delta T} \iff Q = mc\Delta T \quad (\text{J kg}^{-1}\,\text{K}^{-1}).$$

Worked example. Heat 0.50 kg of water from 20 to 100 °C ($c = 4200$): $\Delta T = 80$, so $Q = 0.50 \times 4200 \times 80 = 1.68 \times 10^5$ J.

■ Specific latent heat and the heating curve

Latent heat $Q = mL$ is the energy for a **change of state** at constant temperature — **fusion** (melting) or **vaporisation** (boiling). On a heating curve the **sloped** parts heat one phase ($Q = mc\Delta T$); the **flat plateaus** are changes of state ($Q = mL$):





A heating curve through changes of state

$L_{\text{vap}} > L_{\text{fusion}}$: vaporising must **fully separate** the molecules (and push back the atmosphere), whereas melting only **loosens** the lattice.

■ Measuring c — electrical method

An electrical heater supplies $Q = VIt = Pt$, which equals $mc\Delta T$.

Worked example. A 50 W heater warms 0.30 kg of a liquid by 8.0 K in 100 s (no losses): $Q = Pt = 50 \times 100 = 5000$ J, so $c = \dfrac{Q}{m\Delta T} = \dfrac{5000}{0.30 \times 8.0} = 2100$ J kg^{-1} K^{-1}.

■ Method of mixtures

In an **insulated** container, **energy lost by the hot body = energy gained by the cold body** (include any change of state).

Worked example. A 0.50 kg metal block at 90 °C is put into 0.40 kg of water at 15 °C; they settle at 22 °C. Then $m_{\text{m}}c_{\text{m}}\Delta T_{\text{m}} = m_{\text{w}}c_{\text{w}}\Delta T_{\text{w}}$: $0.50\,c_{\text{m}}(90 - 22) =$

$0.40 \times 4200 \times (22 - 15)$, so $c_\mathrm{m} = \dfrac{11760}{0.50 \times 68} = 346\ \mathrm{J\,kg^{-1}\,K^{-1}}$.

2 Practice

Now apply the methods above.

2.1 Define **specific heat capacity**. [1]

2.2 Find the energy needed to heat 0.50 kg of water from 20 °C to 100 °C ($c = 4200\ \mathrm{J\,kg^{-1}\,K^{-1}}$). [2]

2.3 Define **specific latent heat**. [1]

2.4 Explain, in terms of the separation of the molecules and the work done pushing back the atmosphere, why the specific latent heat of **vaporisation** of a substance is much greater than its specific latent heat of **fusion**. [3]

3 Exam-style questions

3.1 On a heating curve, the **flat** sections represent: [1]

- **A** heating a solid
- **B** a change of state
- **C** cooling
- **D** heating a gas

3.2 A 60 W heater is used to find the specific heat capacity of a 0.25 kg metal block. In 120 s the temperature rises by 9.6 K. Calculate c (assume no heat loss). [3]

3.3 A 0.030 kg ice cube at 0 °C is added to 0.25 kg of water at 15 °C in an insulated cup. All the ice melts and the final temperature is 5.0 °C. ($c_{\text{water}} = 4200$ J kg^{-1} K^{-1}.) Calculate the **specific latent heat of fusion** of ice. [4]

3.4 Explain, in terms of **particles**, why energy is needed to melt a solid even though the temperature does not rise. [2]

3.5 An electric heater of power 2.0 kW is used to warm 0.80 kg of water in an open beaker. The specific heat capacity of water is 4200 J kg^{-1} K^{-1} and its specific latent heat of vaporisation is 2.26×10^6 J kg^{-1}.

(a) **Define** the **specific heat capacity** of a substance. [2]

(b) The water starts at 18 °C. **Determine** the time taken to raise it to 100 °C, assuming no energy is lost. [3]

(c) The heater is left on for a further 4.0 minutes once the water is boiling. **Determine** the mass of water that boils away. [3]

(d) In practice the measured time in **(b)** is longer than the calculated one. **Suggest** two reasons, and **state** which of your calculated answers, (b) or (c), is affected more by them. [3]

Solutions

2.1 The energy needed to raise the temperature of **unit mass** (1 kg) by **one kelvin**.

2.2 $Q = mc\Delta T = 0.50 \times 4200 \times 80 = 1.68 \times 10^5$ J.

2.3 The energy needed to change the state of **unit mass** at **constant temperature**.

2.4 Melting only **loosens** the lattice: the molecules stay about the same distance apart, so only some of the bonds have to be broken. Boiling must separate the molecules **completely**, breaking essentially all of the intermolecular bonds. On top of that, the vapour occupies a far greater volume, so work is done **pushing back the atmosphere** — energy that melting barely needs.

3.1 **B** — a change of state.

3.2 $Q = Pt = 60 \times 120 = 7200$ J; $c = \dfrac{Q}{m\Delta T} = \dfrac{7200}{0.25 \times 9.6} = 3000$ J kg^{-1} K^{-1}.

3.3 Energy lost by the water $= m_w c\Delta T = 0.25 \times 4200 \times (15 - 5) = 10\,500$ J; this melts the ice **and** warms the melted ice from 0 to 5 °C: $10\,500 = 0.030L + 0.030 \times 4200 \times 5$; $0.030L = 10\,500 - 630 = 9870$; $L = 3.3 \times 10^5$ J kg^{-1}.

3.4 The energy is used to **break the bonds** between particles (increase their potential energy / separate them), not to increase their kinetic energy, so the temperature stays constant.

3.5 (a) The energy required to raise the temperature of **unit mass** of the substance by **one kelvin** (or one degree Celsius), without any change of state.
(b) $E = mc\Delta\theta = 0.80 \times 4200 \times (100 - 18) = 2.75 \times 10^5$ J; $t = \dfrac{E}{P} = \dfrac{2.75 \times 10^5}{2000} = 138$ s, about 2.3 minutes.
(c) Energy supplied $= Pt = 2000 \times 240 = 4.8 \times 10^5$ J; $m = \dfrac{E}{L} = \dfrac{4.8 \times 10^5}{2.26 \times 10^6} = 0.21$ kg.
(d) Any two of: thermal energy is lost to the surroundings and to the beaker; the beaker itself must be warmed; some water evaporates before boiling; the heater is not 100% efficient. Part **(c)** is affected more — the water is then at its highest temperature, so the temperature difference with the room is greatest and the rate of energy loss is largest, and it lasts longer.

3 **(a)** Define specific latent heat.

....

....

.... [2]

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

....

....

....

....

.... [3]

(c) An ice cube of mass 37.0 g at temperature 0.0 °C is placed in a beaker containing water of mass 208 g at temperature 26.4 °C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is 10.3 °C.

The specific heat capacity of water is 4.18 $J g^{-1} °C^{-1}$.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water.

specific latent heat of fusion = ... $J g^{-1}$ [4]

[Total: 9]

3 **(a)** Define specific heat capacity.

....

....

.... [2]

(b) A block of aluminium has a volume of $3.612 \times 10^{-3}\,m^3$ at a temperature of 0 °C.

Aluminium has a density of $2.700 \times 10^3\,kg\,m^{-3}$ at 0 °C.
It has a density of $2.620 \times 10^3\,kg\,m^{-3}$ at 500 °C.

The block is heated so that its temperature increases from 0 °C to 500 °C at an atmospheric pressure of $1.01 \times 10^5\,Pa$.
The increase in internal energy of the block is 4.38 MJ.

(i) Calculate the mass of the block.

mass = ... kg [2]

(ii) Show that the volume of the block at a temperature of 500 °C is $3.722 \times 10^{-3}\,m^3$.

[1]

(iii) Use the information in **(b)(ii)** to determine the magnitude of the work done on the block when its temperature is raised from 0 °C to 500 °C.

work done = ... J [2]

(iv) Explain whether the work done on the block is positive or negative.

....

....

.... [2]

(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer.

specific heat capacity = ... unit .... [3]

(c) Without further calculation, suggest with a reason how doubling the pressure in **(b)** is likely to affect the answer in **(b)(v)**.

....

....

.... [1]

[Total: 13]

3 **(a)** Define specific latent heat.

....

....

.... [2]

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

....

....

....

....

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(c) An ice cube of mass 37.0 g at temperature 0.0 °C is placed in a beaker containing water of mass 208 g at temperature 26.4 °C.

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Determine a value, to three significant figures, for the specific latent heat of fusion of water.

specific latent heat of fusion = ... $J\,g^{-1}$ [4]

[Total: 9]

2 **(a)** State what is meant by two objects being in thermal equilibrium.

....

....

.... [2]

(b) A mass X of ice at 0 °C is placed in a beaker containing a mass M of water at Celsius temperature t. The beaker is perfectly insulated and has negligible heat capacity. After some time, the ice that was added reaches thermal equilibrium with the original water in the beaker.

The specific latent heat of fusion of water is L. The specific heat capacity of water is c.
The final Celsius temperature of the system is θ.

Give expressions, in terms of some or all of X, M, t, θ, L and c, for the thermal energy:

(i) E_1, gained by the ice as it melts to become water at 0 °C

E_1 = ... [1]

(ii) E_2, lost by the water as its Celsius temperature decreases from t to θ

E_2 = ... [1]

(iii) E_3, gained by the melted ice as its Celsius temperature increases from 0 °C to θ.

E_3 = ... [1]

(c) Use your answers in **(b)** to show that the final Celsius temperature θ of the system is given by

$$\theta = \frac{Mct - XL}{c(M + X)}.$$

[2]

[Total: 7]