2.2 Thermal properties and temperature

Name: _____ Class: _____ Date: _____ **Total: 32 marks**

0 Vocabulary

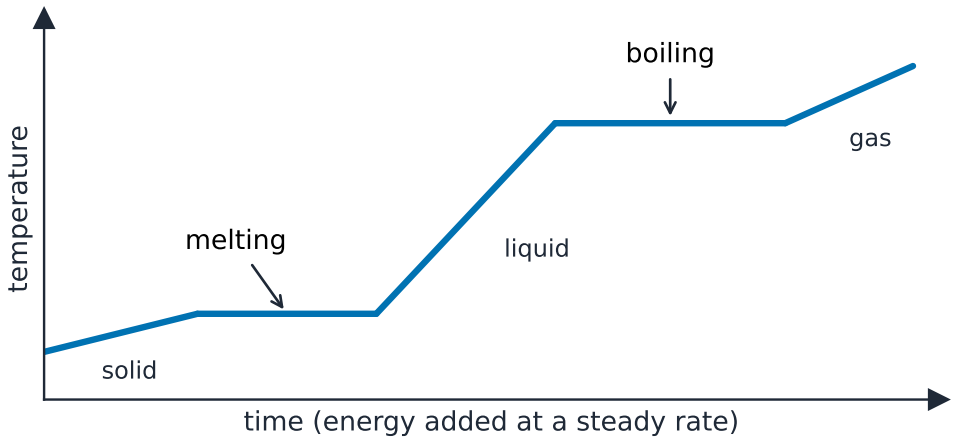
Word	Example
solidification /səˌlɪdɪfɪ'keɪʃn/ 凝固	Cooling the molten metal causes **solidification**. 冷却熔融金属会使其**凝固**。
absolute zero 绝对零度 /'æbsəluːt 'zɪərəʊ/	Nothing can be colder than **absolute zero**. 任何东西的温度都不可能低于**绝对零度**。
kelvin /'kelvɪn/ 开尔文	Water freezes at 273 **kelvin**. 水在 273 **开尔文**时结冰。
↔ **thermal expansion** 热膨胀 /'θɜːml ek'spænʃn/	**Thermal expansion** makes sea water take up more space as it warms. 海水变暖时，**热膨胀**使它占据更大的空间。
internal energy 内能 /ɪn'tɜːnl 'enədʒi/	Heating the gas raises its **internal energy**. 加热气体会增加它的**内能**。
specific heat capacity 比热容 /spə'sɪfɪk hiːt kə'pæsɪti/	Water has a high **specific heat capacity**, so it warms up slowly. 水的**比热容**很大，所以升温慢。
heater /'hiːtə/ 加热器	The **heater** warms the water. **加热器**给水加热。
thermometer /θɜː'mɒmɪtə/ 温度计	Put the **thermometer** in the water. 把**温度计**放入水中。
insulating material 隔热材料 /'ɪnsjuːleɪtɪŋ mə'tɪərɪəl/	Wool is a good **insulating material**. 羊毛是一种很好的**隔热材料**。
melting /'meltɪŋ/ 熔化	**Melting** turns ice into water. **熔化**使冰变成水。
evaporation /ɪˌvæpə'reɪʃn/ 蒸发	**Evaporation** dries wet clothes. **蒸发**使湿衣服变干。
cools down /kuːlz daʊn/ 冷却	A cup of tea **cools down** over time. 一杯茶会随着时间推移而**冷却**。

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Word	Example
independent variable 自变量 /ˌɪndɪˈpendənt ˈveərɪəbl/	The **independent variable** is the one you change. **自变量**是你改变的变量。
dependent variable 因变量 /dɪˈpendənt ˈveərɪəbl/	The **dependent variable** is the one you measure. **因变量**是你测量的变量。
control variables 控制变量 /kənˈtrəʊl ˈveərɪəblz/	Keep the **control variables**, such as the temperature, the same. 保持**控制变量**不变，例如温度。
parallax /ˈpærəlæks/ 视差	Look straight at the scale to avoid **parallax** errors. 正对刻度读数，以避免**视差**造成的误差。

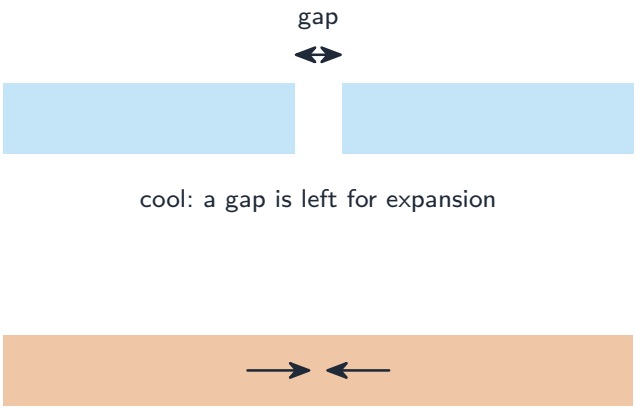
1 Key knowledge and worked examples

■ Specific heat capacity



plateau: energy changes the state, so the temperature stays constant

During melting and boiling the temperature stays flat while energy is still added



Solids expand on heating – a gap is left so the track does not buckle

Heat 2.0 kg water by 50 °C ($c = 4200$): $\Delta E = mc\Delta\theta = 2.0 \times 4200 \times 50 = 420\,000$ J.

■ The state changes, and measuring c

Condensation 凝结 is a gas becoming a liquid: the particles slow down, come close together and the attractions hold them. **Solidification** 凝固 is a liquid becoming a solid: the particles lose more energy and settle into fixed positions in a lattice. During melting and boiling the temperature does not change, because the energy goes into breaking the forces between particles rather than into speeding them up.

Thermal expansion. Heated particles vibrate or move more and take up more space. Gases expand most, then liquids, then solids, because the forces between particles are weakest in a gas and strongest in a solid. Everyday consequences: gaps between railway rails, rollers under a bridge, a tight metal lid freed by hot water, and a liquid-in-glass thermometer working at all.

Measuring specific heat capacity. Use a metal block with two holes, one for an electric heater and one for a thermometer. Measure the mass m; switch the heater on for a measured time t, recording I and V, so the energy supplied is $E = IVt$; record the temperature rise $\Delta\theta$ and use $c = \dfrac{E}{m\,\Delta\theta}$. For a liquid, heat a known mass in a container and stir it. Insulate the block or container, because energy escaping to the air makes the value of c come out too large.

Worked example. A 2.0 kg block is heated by a 50 W heater for 5.0 minutes and rises from 7.0 °C to 22.0 °C. Energy supplied $= Pt = 50 \times 300 = 15\,000$ J; $\Delta\theta = 15.0$ °C; $c = \dfrac{15\,000}{2.0 \times 15.0} = 500$ J/(kg °C).

2 Practice

2.1 Convert 25 °C to kelvin. [1]

25 °C

2.2 State why a liquid cools as it evaporates. [1]



2.3 Describe condensation and solidification in terms of particles. [2]

condensation solidification

2.4 Explain why a gas expands more than a solid for the same temperature rise. [2]

gas solid

2.5 State two everyday consequences of thermal expansion. [2]

thermal expansion

3 Exam-style questions

3.1 While a pure solid is melting, its temperature: [1]



☐ **A** rises steadily
B stays constant
C falls
D rises then falls

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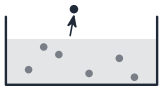
3.2 A 0.50 kg metal block is given 9000 J of energy and its temperature rises by 40 °C.

(a) Find the specific heat capacity of the metal. [3]



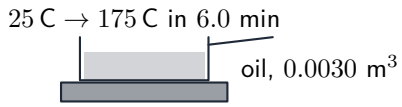
(b) State one reason the actual value might be higher than calculated. [1]

3.3 Explain, using the particle model, why evaporation cools the remaining liquid. [2]



3.4 A pan contains 0.0030 m^3 of cooking oil. The oil is heated for 6.0 min and its temperature rises from 25 °C to 175 °C. The density of the oil is 900 kg/m^3 and its specific heat capacity is 2000 J/(kg °C).

(a) Calculate the mass of oil in the pan. [2]



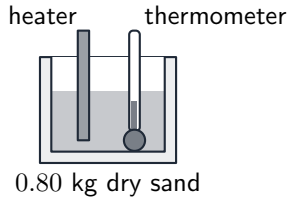
(b) Calculate the energy needed to raise the temperature of the oil. [2]

(c) Calculate the power needed to supply this energy in 6.0 min. [2]

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3.5 A student measures the specific heat capacity of sand. She puts 0.80 kg of dry sand in an insulated pot with an electric heater and a thermometer.

(a) Describe the measurements she must take. [3]



(b) The 50 W heater runs for 4.0 minutes and the temperature rises from 7.0 °C to 22.0 °C. Calculate the energy supplied. [2]

(c) Calculate the specific heat capacity of the sand. [3]

(d) Her value is larger than the true value. Explain why, and state one improvement. [2]

(e) The heater is left on and the temperature of the sand stops rising. Explain why. [1]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- $T = 25 + 273 = \mathbf{298}$ K

2.2

- the fastest particles escape, lowering the average energy of those left

2.3

- condensation: the gas particles slow down and come close enough for the attractions between them to hold them as a liquid
- solidification: the liquid particles lose more energy and settle into fixed positions in a regular pattern

2.4

- the forces between gas particles are very weak, so they are free to spread much further apart
- in a solid strong forces hold the particles in a lattice, so they only vibrate a little more

2.5

- any two of: gaps left between railway rails; a bridge resting on rollers; a tight metal lid loosened in hot water; the liquid rising in a thermometer

3.1 B

- the temperature stays constant during a change of state

3.2

(a) $c = \Delta E/(m\Delta\theta)$

$$c = \frac{E}{m\,\Delta\theta} = \frac{9000\text{ J}}{(0.50\text{ kg})(40\text{ °C})} = \mathbf{450}\text{ J/(kg °C)}$$

(b) some energy is lost to the surroundings, so more than 9000 J was really needed

3.3

- the most energetic particles leave the surface
- so the average kinetic energy – and the temperature – of the remaining particles falls

3.4

(a)

- density $\rho = \dfrac{m}{V}$, so $m = \rho V$

$$m = \rho V = (900\text{ kg/m}^3)(0.0030\text{ m}^3) = \mathbf{2.7}\text{ kg}$$

(b)

- energy to heat a mass: $\Delta E = mc\Delta\theta$, with $\Delta\theta = 175\,°\text{C} - 25\,°\text{C} = 150\,°\text{C}$

$$\Delta E = mc\Delta\theta = (2.7\text{ kg})(2000\text{ J/(kg °C)})(150\,°\text{C}) = \mathbf{8.1 \times 10^5}\text{ J}$$

(c)

- power is energy per unit time, $P = \dfrac{E}{t}$, with $t = 6.0 \times 60\text{ s} = 360\text{ s}$

$$P = \frac{E}{t} = \frac{8.1 \times 10^5\text{ J}}{360\text{ s}} = \mathbf{2300}\text{ W}$$

3.5

(a) the mass of the sand

- the temperature before and after heating, giving the rise
- the time the heater is on together with its power, or the current and voltage, giving the energy

(b) $E = Pt$

$$E = Pt = (50\text{ W})(4.0 \times 60\text{ s}) = \mathbf{12\,000}\text{ J}$$

(c) $\Delta\theta = 22.0\text{ °C} - 7.0\text{ °C} = 15.0\text{ °C}$

- $c = E/(m\Delta\theta)$

$$c = \frac{E}{m\,\Delta\theta} = \frac{12\,000\text{ J}}{(0.80\text{ kg})(15.0\text{ °C})} = \mathbf{1000}\text{ J/(kg °C)}$$

(d) some supplied energy escapes to the surroundings instead of heating the sand, so the calculated c is too large

- add more insulation, or a lid

(e) the sand is losing energy to the surroundings as fast as the heater supplies it, so there is no net gain

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