Unit 12 · Heat

ANSWER KEY · FOR TEACHERS

Full marks 50

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. evaporation
2. volatile
3. superficial
4. cubical
5. bimetallic
6. latent
7. fusion
8. heat equation

Each carries 0.5 mark. K · 4

2 Label the diagram

1. brass
2. iron
3. contact
4. gap

Each carries 0.5 mark. K · 2

3 True or false

i. ✗ **False**: Evaporation takes heat away from the surroundings; cold isn't a thing that flows.

ii. ✓ **True**

iii. ✗ **False**: The hole gets bigger, as if the whole plate were enlarged.

iv. ✓ **True**

v. ✗ **False**: They have the same kinetic energy but more potential energy.

vi. ✓ **True**

Each carries 0.5 mark. U · 3

4 Multiple choice

i. **c.** humid air above it — U · 1

Humid air already holds a lot of water vapor, so many molecules return to the water and evaporation slows. Warmth, wind and a larger surface all speed it up.

ii. **b.** J/kg — K · 1

$L = Q/m$: joules divided by kilograms. There is no temperature in it, because the temperature doesn't change while the state changes.

iii. **b.** brass expands more than iron — U · 1

Brass expands about one and a half times as much as iron. Joined along their length, the longer brass must lie on the outside of the curve.

iv. **b.** 1,130,000 J — A · 1

$Q = mL = 0.5 \times 2{,}260{,}000 = 1{,}130{,}000$ J. (4,520,000 J would be 2 kg; 210,000 J is warming 0.5 kg of water by 100 °C.)

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v. **c.** in boiling, each molecule must break completely free of its neighbors and push back the air U · 1

In melting, the molecules only loosen and still touch and pull on each other. In boiling they are pulled right apart, and the vapor must push back the atmosphere to make room. That takes far more energy for each kilogram.

5 Very short answers

a. MARKING SCHEME K · 1

✓ 336,000 J/kg written.

b. MARKING SCHEME U · 1

✓ The opening of the lid grows on heating.

c. MARKING SCHEME A · 1

✓ 168,000 J worked out.

6 Short answers

a. MARKING SCHEME U · 2

✓ Ice must first melt, taking in 336,000 J for each kilogram from the drink at a constant temperature.

✓ Water at 0 °C only takes in heat by warming, so the ice takes far more heat from the drink.

b. MARKING SCHEME U · 2

✓ Steam first condenses on the skin, giving out its latent heat (2,260 J for every gram).

✓ Only then does it cool like boiling water, so the same mass gives the skin about ten times as much heat.

c. MARKING SCHEME U · 2

✓ Wires contract in cold weather.

✓ Hung tight, they could snap in winter; the sag leaves room for them to get shorter.

d. MARKING SCHEME K · 2

✓ Evaporation happens only at the surface; boiling happens all through the liquid, with bubbles.

✓ Evaporation happens at any temperature; boiling at a fixed temperature, the boiling point (or any other correct difference).

7 Long answers

a. ANSWER U · 4

Evaporation is the change of a liquid into its vapor from its surface, at any temperature below its boiling point.

The molecules of a liquid move with a range of speeds, and the temperature depends on their average kinetic energy. Only the fastest molecules at the surface have enough energy to break free of the attraction of their neighbors and escape into the air. When the most energetic molecules leave, the average kinetic energy of the molecules left behind falls, so the temperature of the liquid falls. Heat then flows into the liquid from its surroundings, so they cool too. This is the cooling effect of evaporation, seen in sweating and in the clay *matka*.

MARKING SCHEME

✓ Evaporation is the change of a liquid into vapor from its surface, at any temperature below its boiling point.

✓ The molecules have a range of speeds, and only the fastest at the surface can break free and escape.

✓ The average kinetic energy of those left falls, so the temperature of the liquid falls.

✓ Heat flows in from the surroundings, so they cool too.

b. ANSWER

Latent heat is the heat absorbed or given out by a substance during a change of state, without any change in its temperature.

The temperature of a substance depends on the average kinetic energy of its molecules. In ice, the molecules are held in fixed places by their attraction for each other. At 0 °C, the heat supplied doesn't make them vibrate any faster; it is used to pull them free of their fixed places against those forces,

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which increases their potential energy. Since their kinetic energy doesn't change, the temperature stays at 0 °C until all the ice has melted. Only then does the heat raise the molecules' kinetic energy again, and the temperature rises. U · 4

MARKING SCHEME

- ✓ Latent heat: the heat absorbed or given out during a change of state, without a change in temperature.
- ✓ The temperature depends on the average kinetic energy of the molecules.
- ✓ At 0 °C the heat pulls the molecules free of their fixed places, raising their potential energy.
- ✓ The kinetic energy doesn't change, so the temperature stays at 0 °C until all the ice has melted.

8 Numerical problems

a. **ANSWER** A · 3

Warm: $Q_1 = 0.1 \times 4{,}200 \times 80 = 33{,}600$ J
Boil: $Q_2 = 0.1 \times 2{,}260{,}000 = 226{,}000$ J
$Q = 33{,}600 + 226{,}000 =$ **259,600 J.**

MARKING SCHEME

- ✓ Warm: $0.1 \times 4{,}200 \times 80 = 33{,}600$ J.
- ✓ Boil: $0.1 \times 2{,}260{,}000 = 226{,}000$ J.
- ✓ Total 259,600 J.

b. **ANSWER** A · 4

Warm the ice: $1 \times 2{,}100 \times 10 = 21{,}000$ J
Melt it: $1 \times 336{,}000 = 336{,}000$ J
Warm the water: $1 \times 4{,}200 \times 100 = 420{,}000$ J
Boil it: $1 \times 2{,}260{,}000 = 2{,}260{,}000$ J
Total = **3,037,000 J** (about 3.04×10^6 J). Boiling takes $2{,}260{,}000 \div 3{,}037{,}000 =$ **about 74%** of it.

MARKING SCHEME

- ✓ Warm the ice 21,000 J; melt it 336,000 J.
- ✓ Warm the water 420,000 J; boil it 2,260,000 J.
- ✓ Total 3,037,000 J.
- ✓ Boiling takes about 74%.

c. **ANSWER** A · 4

Heat lost: $0.2 \times 4{,}200 \times (25 - T) = 840(25 - T)$
Heat gained: $0.04 \times 336{,}000 + 0.04 \times 4{,}200 \times T = 13{,}440 + 168T$
$21{,}000 - 840T = 13{,}440 + 168T$
$7{,}560 = 1{,}008T$, so $T = 7.5$ °C.
7.5 °C. (Check: the water could give 21,000 J by cooling to 0 °C, more than the 13,440 J the ice needs to melt, so all the ice does melt.)

MARKING SCHEME

- ✓ Heat lost: $0.2 \times 4{,}200 \times (25 - \mathrm{T}) = 840(25 - \mathrm{T})$.
- ✓ Heat gained: $0.04 \times 336{,}000 + 0.04 \times 4{,}200 \times \mathrm{T} = 13{,}440 + 168\mathrm{T}$.
- ✓ $21{,}000 - 840\mathrm{T} = 13{,}440 + 168\mathrm{T}$, so $7{,}560 = 1{,}008\mathrm{T}$.
- ✓ $\mathrm{T} = 7.5$ °C.

d. **ANSWER** A · 3

Heat gained by the water: $0.5 \times 4{,}200 \times 60 = 126{,}000$ J
Heat lost by m kg of steam: $m \times 2{,}260{,}000 + m \times 4{,}200 \times 20 = 2{,}344{,}000\,m$
$2{,}344{,}000\,m = 126{,}000$, so $m = 0.0538$ kg.
About 54 g of steam.

MARKING SCHEME

- ✓ Heat gained by the water: $0.5 \times 4{,}200 \times 60 = 126{,}000$ J.
- ✓ Heat lost by the steam: $\mathrm{m} \times 2{,}260{,}000 + \mathrm{m} \times 4{,}200 \times 20 = 2{,}344{,}000$ m.
- ✓ $\mathrm{m} \approx 0.054$ kg, about 54 g.

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9 Think

ANSWER HA · 3

Heat lost by the juice = heat gained by the cold water:
$0.25 \times 4{,}200 \times (30 - T) = 0.05 \times 4{,}200 \times T$
$7.5 - 0.25T = 0.05T$, so $T = 25$ °C.
25 °C, against 11.7 °C with ice. The ice takes 16,800 J from the juice just to melt, without warming at all, before its water starts to warm like the cold water. That latent heat does most of the cooling.

MARKING SCHEME

- ✓ $0.25 \times 4{,}200 \times (30 - \mathrm{T}) = 0.05 \times 4{,}200 \times \mathrm{T}$.
- ✓ $\mathrm{T} = 25$ °C.
- ✓ The ice takes 16,800 J from the juice just to melt, before its water starts to warm: the latent heat does most of the cooling.

10 Activity: Which dries first?

(not marked)

WHAT STUDENTS SHOULD FIND

A dries before B (surface area); D before C (moving air); A before C (temperature). E is still damp hours later: only its outside can lose water, and the air inside the bowl soon fills with vapor (humidity).

See it at Science Playground

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- **Galileo Thermometer** (exhibit): As the liquid warms it expands and becomes less dense, so the bulbs sink one by one: thermal expansion read as a temperature.
- **Lava Lamp — Convection in Motion** (exhibit): Heated at the bottom, the wax expands and its density falls, so it rises; cooled at the top, it contracts and sinks again.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	21	16	3	**50**

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