Exercise walk-through

Temperature scales ▪ 14.2

eXercise

You must be able to

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

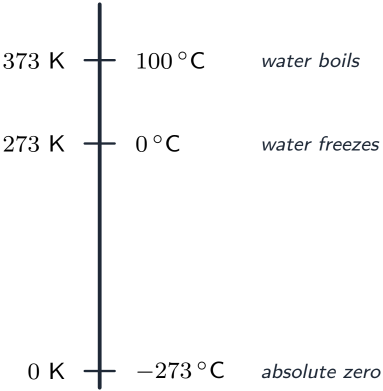
Method — Thermometers

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**.

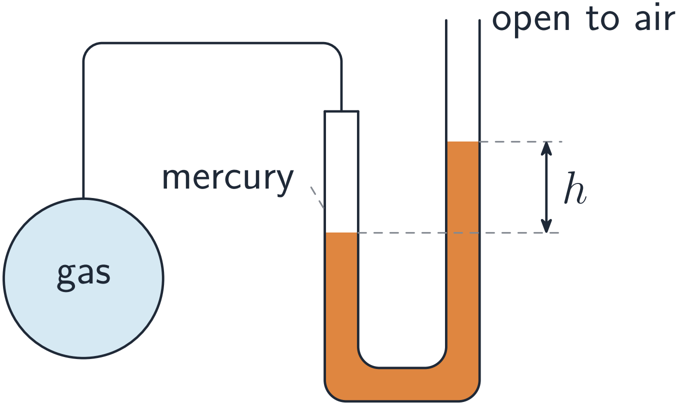
Method — The two scales

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

The **thermodynamic** scale does **not** depend on any one substance. The lowest possible temperature is **absolute zero** ($0\ \mathsf{K} = -273.15\ {}^\circ\mathsf{C}$), where a system has its least internal energy.



Method — The two scales



A gas thermometer and absolute zero

Practice 2.1 ▪ 1 mark

Convert $27\ ^{\circ}\mathrm{C}$ to **kelvin**.

Solution 2.1

Method: The two scales

Worked steps

$T = 27 + 273 = 300$ K **B1**.

Practice 2.2 ▪ 1 mark

Convert 200 K to **degrees Celsius**.

Solution 2.2

Method: The two scales

Worked steps

$\theta = 200 - 273 = -73\ ^\circ\mathrm{C}$ **B1**.

Practice 2.3 ▪ 1 mark

State the value of **absolute zero** in $^\circ$C.

Solution 2.3

Method: The two scales

Worked steps

$-273\ ^{\circ}\mathrm{C}\ (-273.15)$ **B1**.

Practice 2.4 ▪ 2 marks

Name **two** physical properties used in thermometers.

Solution 2.4

Method: Thermometers

Worked steps

Any two: density of a liquid; volume of a gas; resistance of a metal; e.m.f. of a thermocouple **B1** **B1**.

Exam-style 3.1 ▪ 1 mark

A temperature of 100 °C in kelvin is:

A 173 K

B 373 K

C 273 K

D 100 K

Solution 3.1

Method: The two scales

A 173 K

B 373 K ✓

C 273 K

D 100 K

Worked steps

B — 373 K.

Exam-style 3.2 ▪ 2 marks

State what is meant by **absolute zero**.

Solution 3.2

Method: The two scales

Worked steps

The **lowest possible temperature** B1, at which a system has its **minimum internal energy** (least particle motion) B1.

Exam-style 3.3 ▪ 1 mark

Convert 310 K to **degrees Celsius**.

Solution 3.3

Method: The two scales

Worked steps

$\theta = 310 - 273 = 37\ ^{\circ}\mathrm{C}$ **B1**.

Exam-style 3.4 ▪ 2 marks

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

Solution 3.4

Method: The two scales

Worked steps

A property-based scale depends on **how that property changes** (it may not be linear), so different thermometers can disagree **B1**; the thermodynamic scale is defined independently of any substance, so it is consistent **B1**.

Exam-style 3.5 ▪ 1 mark

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,

(ii) the thermodynamic scale, with its unit.

(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.

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

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

(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.

Solution 3.5

Method: The two scales

Worked steps

(a)(i) -273.15 °C **A1**.
(a)(ii) 0 K — the unit is required **A1**.
(b) The gas behaves as an **ideal gas**: $pV \propto T$ with no intercept, which is what $pV = NkT$ predicts **B1**.
(c) $pV = NkT$ **M1**, so $N = \dfrac{340}{1.38 \times 10^{-23} \times 640} = 3.8 \times 10^{22}$ **A1**.
(d) $n = \dfrac{N}{N_A} = \dfrac{3.8 \times 10^{22}}{6.02 \times 10^{23}} = 0.064$ mol **A1**.

Solution 3.5

(e) For an ideal gas $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ **M1**, so $m = \dfrac{3kT}{\langle c^2\rangle} = \dfrac{3 \times 1.38 \times 10^{-23} \times 640}{(1400)^2}$ **M1** $= 1.35 \times 10^{-26}$ kg **A1**; dividing by 1.66×10^{-27} gives 8.1 u **A1**.