A-LEVEL PHYSICS • EXERCISE SHEET

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

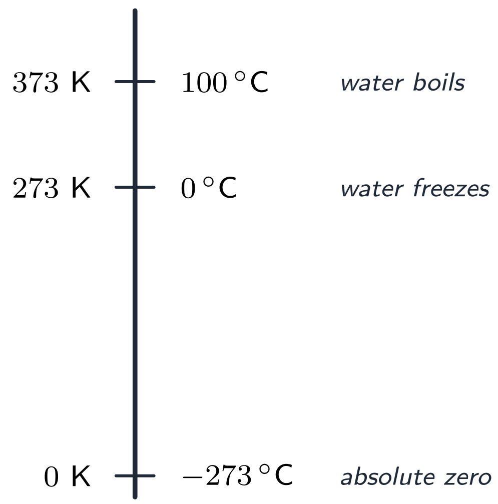
1 Worked examples

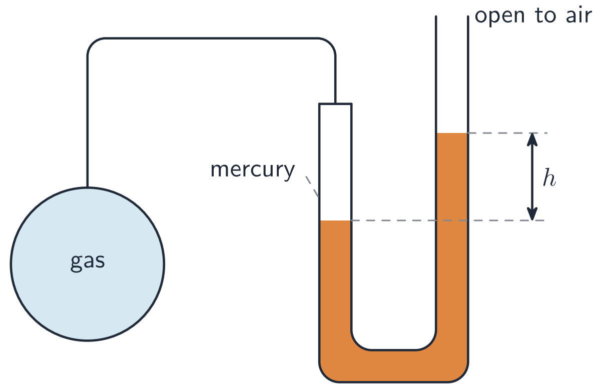
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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.