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** ($T/\text{K} = \theta/°\text{C} + 273.15$)
- explain **absolute zero** and the thermodynamic scale

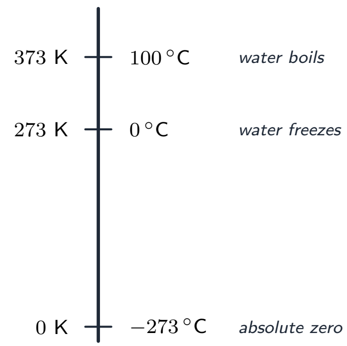
1 Worked examples

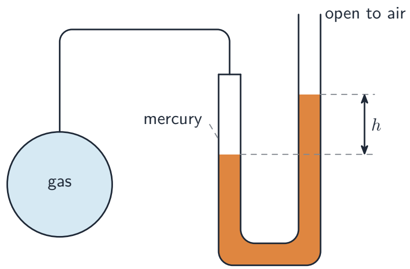
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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

$$T/\text{K} = \theta/°\text{C} + 273.15.$$

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 = 1.66×10^{-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

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

2.1

- $T = 27 + 273 = \mathbf{300}$ K

2.2

- $\theta = 200 - 273 = \mathbf{-73}$ °C

2.3

- $-\mathbf{273}$ °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

- 100 °C = 100 + 273 = **373** K
- **A** is 0 °C; **C** is 100 without converting; **D** is absolute zero in kelvin

3.2

- the **lowest possible temperature**
- at which a system has its **minimum internal energy** (least particle motion)

3.3

- $\theta = 310 - 273 = \mathbf{37}$ °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) $-\mathbf{273.15}$ °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) $pV = NkT$

$$N = \frac{340 \text{ Pa m}^3}{(1.38 \times 10^{-23} \text{ J K}^{-1})(640 \text{ K})} = \mathbf{3.8 \times 10^{22}}$$

(d) $n = N/N_{\mathrm{A}}$

$$n = \frac{3.8 \times 10^{22}}{6.02 \times 10^{23} \text{ mol}^{-1}} = \mathbf{0.064} \text{ mol}$$

(e) for an ideal gas $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

$$m = \frac{3kT}{\langle c^2\rangle} = \frac{3 \times (1.38 \times 10^{-23} \text{ J K}^{-1})(640 \text{ K})}{(1400 \text{ m s}^{-1})^2} = 1.35 \times 10^{-26} \text{ kg}$$

$$\frac{1.35 \times 10^{-26} \text{ kg}}{1.66 \times 10^{-27} \text{ kg u}^{-1}} = \mathbf{8.1} \text{ u}$$