

Exercise walk-through

14.2

Temperature scales

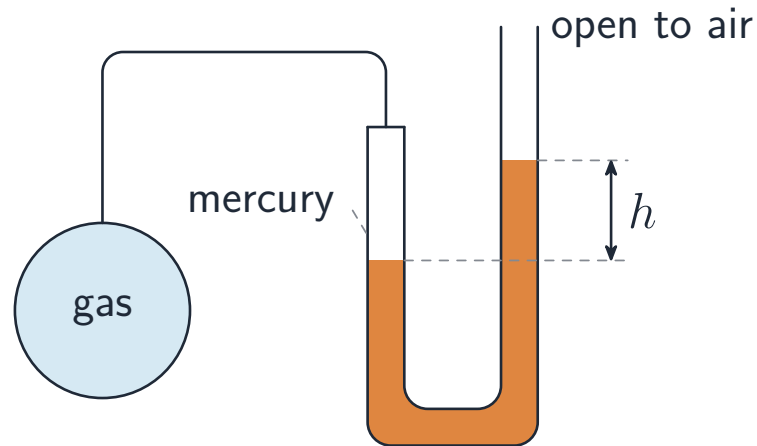
A-Level Physics

Making a thermometer

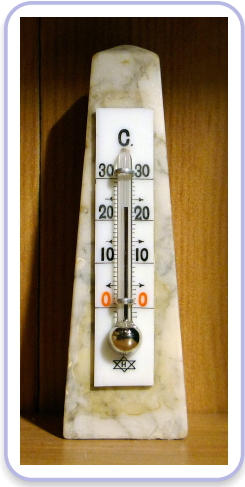
Any property that changes **repeatably** with temperature will do:

- liquid **density** – liquid-in-glass
- gas volume (or pressure) – gas thermometer
- **resistance** of a metal
- **thermocouple** e.m.f.

Two thermometers agree **only at the calibration points** – in between, each follows its own property's curve.



A thermometric property



Any property that varies reproducibly with temperature will do – here the length of a liquid column.

Choosing a thermometric property

what is needed	a property that varies measurably and reproducibly with thermodynamic temperature	
liquid-in-glass	the length of a mercury or alcohol thread in a capillary	tube
resistance	the resistance of a wire or a thermistor – non-linear, but very sensitive	
a thermocouple	two different metals joined at two points; the electromotive force	depends on the temperature difference between the junctions
why a thermocouple	small, fast-responding, and it works over a very wide range	
gas thermometer	the pressure of a fixed volume – the most accurate, and the standard the others are calibrated against	

Sensitivity, range and response time are the three criteria. Naming which one your choice wins on is the mark.

Exercises 2.1-2.3

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 $^{\circ}\text{C}$.

[1]

Exercises 2.1·2.3

2.1 Convert 27 °C to **kelvin**.

[1]

2.1

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

2.2 Convert 200 K to **degrees Celsius**.

[1]

2.2

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

2.3 State the value of **absolute zero** in °C.

[1]

2.3

- $\mathbf{-273\ ^\circ C}$ (-273.15)

Exercises 2.4·3.1

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

[2]

3.1 A temperature of $100\text{ }^{\circ}\text{C}$ in kelvin is:

[1]

☐

A 173 K

B 373 K

C 273 K

D 100 K

Exercises 2.4·3.1

2.4 Name **two** physical properties used in thermometers. [2]

2.4

- any two: density of a liquid; volume of a gas; resistance of a metal; e.m.f. of a thermocouple

3.1 A temperature of 100 °C in kelvin is: [1]

☐

A 173 K

B 373 K

C 273 K

D 100 K

3.1 B

- $100\text{ °C} = 100 + 273 = \mathbf{373\text{ K}}$
- A is 0 °C; C is 100 without converting; D is absolute zero in kelvin

Exercises 3.2-3.4

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]

Exercises 3.2-3.4

3.2 State what is meant by **absolute zero**. [2]

3.2

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

3.3 Convert 310 K to **degrees Celsius**. [1]

3.3

- $\theta = 310 - 273 = \mathbf{37\text{ }^{\circ}\text{C}}$

3.4 Explain why the **thermodynamic** (kelvin) scale is preferred over a scale based on a single physical property. [2]

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

Exercise 3.5 (a)(i)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(a) **State** the temperature of absolute zero on

(i) the Celsius scale,

[1]

Exercise 3.5 (a)(i)

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(a) **State** the temperature of absolute zero on

(i) the Celsius scale,

[1]

(a)(i) **−273.15 °C**

Exercise 3.5 (a)(ii)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(a) **State** the temperature of absolute zero on

(ii) the thermodynamic scale, with its unit.

[1]

Exercise 3.5 (a)(ii)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(a) **State** the temperature of absolute zero on

(ii) the thermodynamic scale, with its unit.

[1]

(a)(ii) **0 K** – the unit is required

Exercise 3.5 (b)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(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]

Exercise 3.5 (b)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(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]

(b) the gas behaves as an **ideal gas**: $pV \propto T$ with no intercept, which is what $pV = NkT$ predicts

Exercise 3.5 (c)

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(c) At one point on that line, $pV = 340 \text{ J}$ and $T = 640 \text{ K}$. **Determine** the number N of molecules in the sample. [2]

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(c) At one point on that line, $pV = 340 \text{ J}$ and $T = 640 \text{ K}$. **Determine** the number N of molecules in the sample. [2]

(c) $pV = NkT$

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

Exercise 3.5 (d)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

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

[1]

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(d) **Determine** the amount of gas, in moles. [1]

(d) $n = N/N_A$

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

Exercise 3.5 (e)

3.5 A sealed container holds a sample of an ideal gas. The Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$, the Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$ and $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$.

(e) At that temperature the root-mean-square speed of the molecules is $1400 \frac{\text{m}}{\text{s}}$. **Determine** the mass of one molecule, in u. [4]

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(e) At that temperature the root-mean-square speed of the molecules is $1400 \frac{\text{m}}{\text{s}}$. **Determine** the mass of one molecule, in u. [4]

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

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

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