TOPIC 9 Temperature

1 An advantage of the platinum resistance thermometer is that

A it may be used to measure rapidly changing temperatures.

B it has a linear scale, because the resistance of a piece of platinum varies directly as thermodynamic temperature.

C it may be used to measure steady temperatures with very high accuracy.

D it absorbs energy from its surroundings very slowly so that it does not disturb the condition of the body under test when placed in contact with it.

E it is the only type of thermometer that can measure accurately temperatures over 3000 K.

N76/II/25; J84/II/25

2 Thermometers M_1 and M_2 are placed inside an evacuated enclosure X with opaque walls maintained at temperature T. The thermometers are identical except that the bulb of M_1 is blackened. If T_1 and T_2 are the temperature indicated by M_1 and M_2 respectively after thermal equilibrium has been established.

A $T_1 > T_2 > T$

B $T_1 > T > T_2$

C $T_1 = T_2 = T$

D $T_1 = T > T_2$

E $T_1 > T = T_2$

N76/II/26; N82/II/26; J83/II/25; N81/II/30

3 The triple point of water has been chosen as the fixed point for the establishment of the kelvin, rather than the melting point of ice, because

A it is more precisely reproducible.

B it is closer to the defining temperature of 273.16 K.

C it gives a more convenient scale between 0 °C and 100 °C.

D very accurate gas thermometers have shown that it is better.

E it ensures a more linear scale for gas thermometers.

J77/II/25

4 A solid X is in thermal equilibrium with a solid Y, which is at the same temperature as a third solid Z. The three bodies are of different materials and masses. Which one of the following statements is certainly correct?

A X and Y have the same heat capacity.

B Y and Z have the same internal energy.

C There is no net transfer of energy if X is placed in thermal contact with Z.

D It is not necessary that Y should be in thermal equilibrium with Z.

E it is not necessary that X should be at the same temperature as Y.

N77/II/25

5 When one junction X of a thermocouple is placed in melting ice and the junction Y in steam at 100 °C, the e.m.f. is 6.0 mV. Junction X is removed from the melting ice and is placed in a liquid bath at a constant temperature, junction Y remaining in steam. The e.m.f. is now −1.5 mV. The temperature of the bath on the centigrade scale of this thermocouple is

A −75°

B −25°

C 25°

D 75°

E 125°

N77/II/26

6 The kelvin, the SI unit of thermodynamic temperature, is defined as

A one-hundredth of the temperature difference between the ice-point and the steam-point

B one-hundredth of the temperature difference between the triple-point of water and the steam-point.

C the fraction 1/273.16 of the thermodynamic temperature of triple-point of water.

D the fraction 1/373.15 of the thermodynamic temperature of the steam-point.

E −273.16 °C.

N77/II/27

7 For the construction of a thermometer, one of the essential requirements is a thermometric substance which

A remains liquid over the entire range of temperatures to be measured.

B has a property that varies linearly with temperature.

C has a property that varies with temperature.

D obeys Boyle's law.

E has a constant expansivity.

J78/II/26

8 An empirical centigrade scale of temperature is set up by finding the values p_{steam} and p_{ice} of a quantity p at the steam- and ice-points and diving the interval into one hundred equal divisions.

When the quantity p has a value p_t, the centigrade temperature t on the scale of that thermometer is given by

A $t = 100 \dfrac{p_t}{p_{steam} - p_{ice}}$ degrees

B $t = 100 \dfrac{p_t - p_{ice}}{p_{steam} - p_{ice}}$ degrees

C $t = 100 \dfrac{p_{steam} - p_t}{p_{steam} - p_{ice}}$ degrees

D $t = 273.16 \lim_{p \to 0} \dfrac{p_t}{p_{ice}}$ degrees

E $t = 373.15 \lim_{p \to 0} \dfrac{p_t}{p_{steam}}$ degrees

N78/II/26; N81/II/25

9 The values of the pressure and volume of a fixed mass of gas in a gas thermometer at the triple point of water are

$$p_{tr} = 1.00 \times 10^5 \text{ Pa} ; V_{tr} = 1.00 \times 10^{-3} \text{ m}^3.$$

When the pressure of the gas is 1.10×10^5 Pa and its volume is 1.20×10^{-3} m^3, the temperature of the gas is

A 207 K
B 250 K
C 273 K
D 298 K
E 361 K

N79/II/26; N85/I 24

10 A sample of an ideal gas gives the isotherms shown below (Fig. 1), where T_1 = 273.15 K, the ice-point, and T_2 is the boiling point of water at standard pressure.

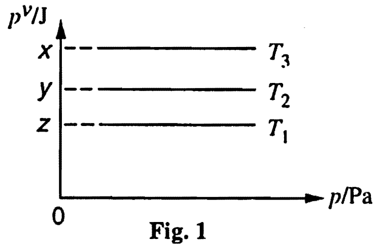


Fig. 1

The magnitude of the thermodynamic temperature T_3 in kelvins is

A $273.15\dfrac{x-y}{y-z}$

B $273.15\dfrac{x}{z}$

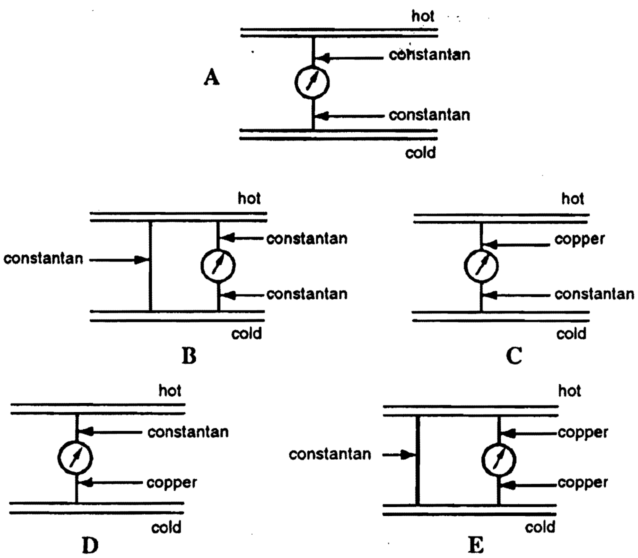
C $273.15 + 100\dfrac{x}{z}$

D $273.15 + 100\dfrac{x-y}{y-z}$

E $273.15 + 100\dfrac{x}{y}$

J82/II/29

11 A cold-water pipe and a hot-water pipe are both made of copper and are initial electrically isolated. In which one of the following arrangements will the galvanometer indicate a thermo-electric current?



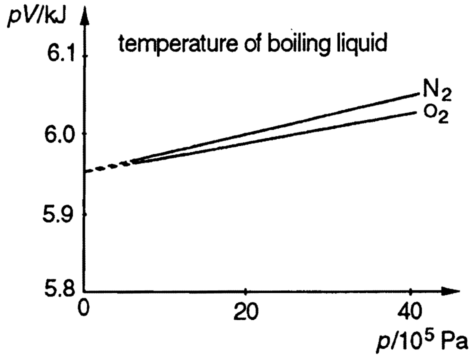
N82/II/27

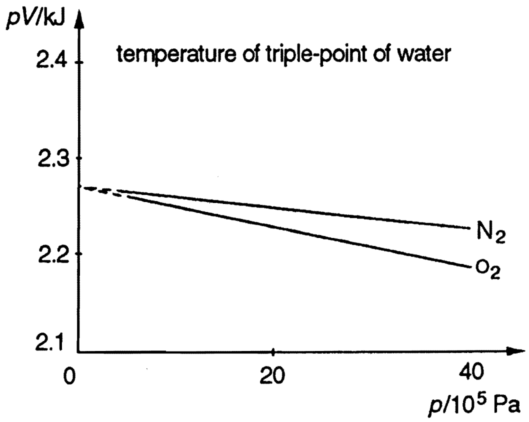
12 Two thermometers X and Y are placed inside an enclosure whose walls are maintained at a steady temperature T. When equilibrium is established, X and Y will give the same reading T

A under all circumstances.
B only if they absorb radiation at equal rates.
C only if both are perfect absorbers.
D only if they have equal thermal capacities.
E only if the enclosure is evacuated.

N83/II/27

13





The graphs above show how pV varies with p for one mole of nitrogen gas and one mole of oxygen gas at the temperature of a boiling liquid and at the temperature of the triple point of water. What is the probable temperature of the boiling liquid?

A 104 K
B 262 K
C 273 K
D 373 K
E 716 K

N84/II/25

14 Which one of the following thermometers would be most suitable for monitoring the temperature of gases in a factory chimney if the temperature can vary over a range of 200 K in a minute?

A alcohol in glass
B mercury in glass
C constant-volume gas
D thermoelectric
E platinum resistance

N85/I/23

15 What is 273.00 K on the Celsius scale of temperature?

A −0.15° C
B 0.00°C
C 0.15°C
D 273.15° C
E 546.15°C J86/I/24

16 A fixed mass of an ideal gas is maintained at constant volume. The pressure of the gas at the triple point of water is p_{tr}. What is the thermodynamic temperature of the gas when its pressure is p?

A $273.16\left(\frac{p_{tr}}{p}\right)$ K
B $273.16\left(\frac{p}{p_{tr}}\right)$ K
C $273.16\left(\frac{p-p_{tr}}{p_{tr}}\right)$ K
D $273.16\left(\frac{p-p_{tr}}{p}\right)$ K
E $273.16\left(\frac{p+p_{tr}}{p_{tr}}\right)$ K J87/I/23

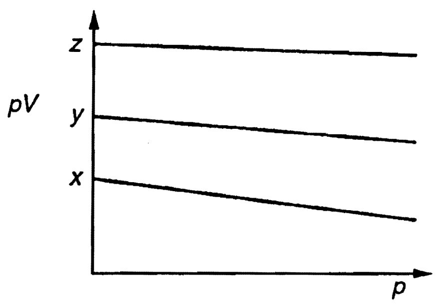
17 Which thermodynamic temperature is equivalent to 501.85 °C?

A 775.00 K
B 774.85 K
C 228.85 K
D 228.70 K
J88/I/26; J95/I/23

18 Which of the following is a useful property of the platinum resistance thermometer?

A It may be used to measure rapidly changing temperatures.
B It may be used to measure steady temperatures with very high accuracy.
C It has a linear scale, because the resistance of a piece of platinum varies directly as the thermodynamic temperature.
D It absorbs energy from its surroundings very slowly so that it does not disturb the condition of the body under test when placed in contact with it.
E It is the only type of thermometer that can measure accurately temperatures over 3000 K. N88/I/24

19 Measurements are taken to determine the product of the pressure p and the volume V of a sample of a gas for various pressures. The results obtained are shown below for three different temperatures; the triple point of water, the boiling point of water, and T, an unknown thermodynamic temperature lying between the other two.



Which of the following expressions gives the value of T?

A $\frac{(y-x)}{(z-x)}$ 100 K
B $\frac{(y-x)}{(z-x)}$ 273.16 K
C $\frac{x}{y}$ 273.16 K
D $\frac{y}{x}$ 273.16 K
E $\frac{(y-x)}{(z-x)}$ 100 + 273.16 K J89/I/25

20 When one junction **X** of a thermocouple is placed in melting ice and the other junction **Y** in steam at 100 °C, the e.m.f. is 6.0 mV. Junction **Y** is removed from the steam and is placed in a liquid bath at a constant temperature, junction **X** remaining in the ice. The e.m.f. is now −1.5 mV.

What is the temperature of the bath on the centigrade scale of this thermocouple?

A −75°
B −25°
C 25°
D 75°
E 125°
J90/I/24

21 Which of the following instruments would be most suitable to measure a rapidly changing temperature in the range 25 °C to 50 °C assuming that they had all been previously calibrated to give direct read-outs?

A an alcohol-in-glass thermometer
B a clinical thermometer
C a mercury-in-glass thermometer
D a platinum resistance thermometer
E a thermocouple J91/I/23

22 Which combination of thermometers would be most appropriate for measuring the following three temperatures?

	1 temperature at various positions in a flame	*2* boiling point of sulphur (717K)	*3* boiling point of liquid nitrogen (80K)
A	liquid-in-glass	resistance	thermocouple
B	resistance	liquid-in-glass	thermocouple
C	resistance	thermocouple	liquid-in-glass
D	thermocouple	liquid-in-glass	resistance
E	thermocouple	resistance	resistance

N93/I/22

23 The table lists the approximate range, accuracy and response time of different types of thermometer.

thermometer	*range/K*	*accuracy*	*response time*
A	3 – 1750	very good	long
B	30 – 1750	average	short
C	75 – 1550	good	long
D	230 – 630	poor	medium

Which set of properties belongs to a thermocouple?
J94/I/23

24 The temperature of a body at 100 °C is increased by $\Delta\theta$ as measured on the Celsius scale.

How is this temperature change expressed on the Kelvin scale?

A $\Delta\theta + 373$ C $\Delta\theta + 100$
B $\Delta\theta + 273$ D $\Delta\theta$

N97/I/23; N2000/I/24

25 The temperature is to be measured in each of two different situations:

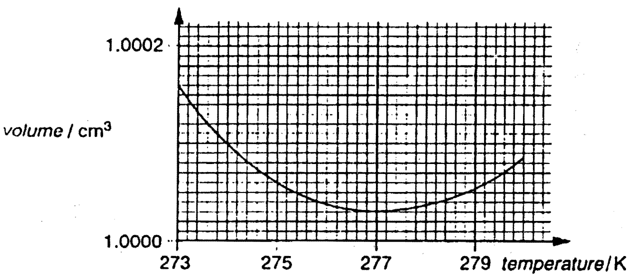
1 recording the temperature of approximately 3 cm^3 of water in an insulated container;
2 monitoring the temperature of a large sphere of copper at approximately 1300 K, cooling at approximately 20 K s^{-1}.

What are the most suitable types of thermometer for these situations?

	1	2
A	resistance	liquid-in-glass
B	resistance	resistance
C	thermocouple	resistance
D	thermocouple	thermocouple

J98/I/23

26 The graph shows how the volume of 1 g of water varies between 273 K and 280 K.



Why would a thermometer, based on the variation of the volume of a fixed mass of water, be unsuitable for measurements in this range?

A The decrease in the volume over this range is greater than its increase.
B The variation of volume is negligible over this range.
C The variation of volume is non-linear over this range.
D The variation of volume is not single-valued over this range. N98/I/23

27 What is a necessary requirement for a thermometer which depends on a particular physical property?

A The property must give an empirical temperature scale which agrees precisely with the absolute scale of temperature over its whole range.
B The property must have a different value at each temperature.
C The property must have zero value at 0 K.
D The thermometer must be capable of use over a very wide range of temperature. N99/I/23

28 The table lists the approximate range and response time of different types of thermometer.

Which set of properties belongs to a liquid-in-glass thermometer?

thermometer	range/K	response time
A	3 – 1750	medium
B	30 – 1750	short
C	75 – 1550	long
D	240 – 630	medium

J2000/I/24

*29 A certain thermocouple thermometer is calibrated by placing its hot and cold junctions in steam and melting ice respectively and measuring an e.m.f. of 5.6 mV with a potentiometer. Subsequently, the thermocouple, of resistance 10 Ω, is used in series with a millivoltmeter of resistance 100 Ω. If the millivoltmeter reads 2.8 mV when the cold junction is in melting ice and the hot junction is in a liquid bath, what is the temperature of the bath on the centigrade scale of this thermometer? J77/I/7

30 The e.m.f. of a certain thermocouple with one junction X in melting pure ice and the other Y in steam from water boiling at standard pressure is 4.1 mV. With Y still in the steam, and X in a certain boiling liquid, the e.m.f. is 11.6 mV, in the same direction as before. Deduce the boiling point of the liquid on the centigrade scale of the thermoelectric thermometer. J85/II/3

31 A certain resistance thermometer has a resistance of 9.97 Ω at the ice-point and 14.04 Ω at the steam-point. Find the temperature on the centigrade scale of this thermometer when its resistance is 11.51 Ω. If the least detectable change of resistance is 0.01 Ω, what is the least change of temperature that can be detected with this thermometer? N85/II/4

32

	Centigrade	*Celsius*	*Kelvin*
Absolute zero	–275.15	–273.15	0.00
Freezing point of water	0.00	0.00	273.15
Triple point of water	0.01	0.01	273.16
Boiling point of water	100.00	100.00	373.15

The above table gives the numerical values of the temperature, to 2 decimal places, of four reference points on three different temperature scales. In each column, two of the values are exact by definition and two are found by experiment. Which, for each scale, are the exact temperatures? [3]

J88/II/4

33 *(b)* State why the thermodynamic scale of temperature is called an absolute scale. [2]

(c) Name types of thermometers that would be suitable for measuring each of the following:

(i) the boiling point of oxygen (about 90K),

(ii) a rapidly changing temperature,

(iii) the temperature of a very small quantity of a liquid. [3]

Give a reason for your choice of thermometer in (ii). [1]
J90/II/6 (part)

34 *(a)* Outline how a physical property which varies with temperature may be used for the measurement of temperature. [2]

(b) How does the absolute (thermodynamic) scale of temperature differ from that described in *(a)*? [2]

(c) Suggest types of thermometer (one in each case) which would be suitable for measuring each of the following:

(i) the melting point of ethanol (about 160 K),

(ii) the temperature inside a blast furnace (about 1800 K). [2]

(d) Briefly discuss whether a thermistor could be used to monitor the variation with time of the temperature of a room. [3] J93/II/6

35 *(a)* State two properties of glass which makes it a particularly suitable material to use in the construction of a mercury-in-glass thermometer. [2]

(b) Contrary to popular opinion, mercury expands only a small amount when it is heated; there are many liquids which expand a great deal more. State two reasons why mercury is still often used in thermometers. [2]

(c) Suggest how the following factors affect the operation of a mercury-in-glass thermometer.

(i) The fact that mercury freezes at 234 K

(ii) The amount of heat required to raise the temperature of the thermometer by 1 K

(iii) The diameter of the bore of the thermometer's capillary tube

(iv) The volume of mercury used in the bulb of the thermometer [7] J96/II/5

36 *(a)* Suggest suitable, and different, thermometers (one in each case) for measuring the following:

(i) the boiling point of oxygen, (about 90 K),

(ii) a rapidly varying temperature to be recorded by remote sensing,

(iii) a small change in human body temperature. [3]
N97/II/7 (part)

Long Questions

37 A thermodynamic temperature may be found from measurements with a constant-volume gas thermometer. The thermodynamic temperature T is given by

$$T = T_{tr} \lim_{p \to 0} (p_T/p_{tr}),$$

where T_{tr}, the thermodynamic temperature of the triple point of water, = 273.16 K and p_T and p_{tr} are the pressures of the gas at T and at the triple point respectively

(b) What is meant by the *triple point of water*

(c) What is the meaning of '$\lim_{p \to 0}$' in the formula for T, and how is it found from the measurements actually taken?

(d) Explain why, when a thermodynamic temperature is found in this way, it is unnecessary to specify what gas is contained in the thermometer.
J76/I/15 (part)

38 *(a)* What features are desirable in a thermometric property if it is to be used for thermometry? Give **two** examples of thermometric properties commonly used.

Considering one type of thermometer as an example, give an equation from which temperatures on an empirical centigrade scale may be derived, and describe briefly how the necessary readings would be taken. (Details of the operation of the thermometer are **not** required.)
J79/I/15 (part)

39 Two bodies are in thermal equilibrium. What does this statement mean?

State the zeroth law of thermodynamics and explain its importance in relation to the use of a thermometer to measure temperature.

(a) The temperature of a hot liquid, measured on the empirical centigrade scale of a certain resistance thermometer is 68.4°

(i) What is meant by describing the resistance thermometer scale as *empirical*?

(ii) Write down an equation which defines the centigrade scale of the thermometer in terms of resistance readings.

**(b)* The element of the resistance thermometer in *(a)* is of mass 0.013 kg and has a specific heat capacity of 4.5×10^2 J K^{-1} kg^{-1}. Initially, it was at room temperature, for which a reading of 17.1° was obtained. It was then completely immersed in 0.30 kg of liquid of specific heat capacity 2.5×10^3 J K^{-1} kg^{-1} giving an equilibrium reading 68.4°.

(i) What was the temperature of the liquid just before the thermometer was immersed? (For the range of temperature of the experiment, assume that the specific heat capacities of the thermometer and the liquid are independent of thermodynamic temperature and that the empirical scale of the resistance thermometer is linear with respect to thermodynamic temperature. Neglect the heat capacity of the container.)

(ii) How could the cooling effect of the thermometer be made less significant?
J83/I/5 (part)

40

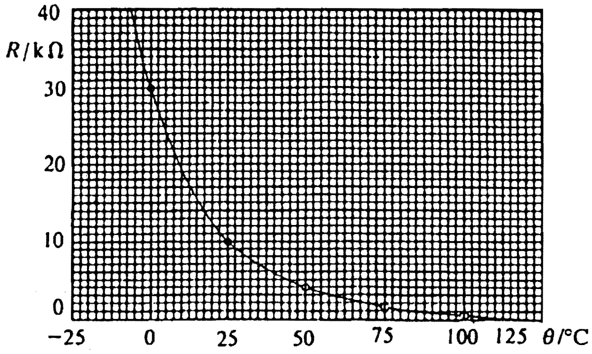


Fig. 2

Fig. 2 shows the way in which the resistance R of a sample of a certain intrinsic semi-conductor depends upon its Celsius temperature θ.

(a) (ii) A theory shows that R is related to thermodynamic temperature T by the equation $R = Ae^{(B/T)}$, where A and B are constants. *Without* carrying out any calculations, state how the experimental points shown on Fig. 2 could be re-plotted to give a linear graph: explain how you would obtain A and B from that graph.

(b) It would be possible to use this semi-conductor sample as a resistance thermometer and to define a centigrade scale of temperature based on changes in its resistance.

(i) Write down the formula relating temperature t on the centigrade scale of this resistance thermometer to the resistance R_t at that temperature and the resistances at the ice- and steam-points, R_i and R_s.

(ii) Read off from Fig. 2 the values of R_i and R_s, and deduce the temperature on this scale to which a resistance of 4.0 kΩ corresponds. Use Fig. 2 to find the equivalent Celsius temperature.

(iii) Comment on the discrepancy between these temperatures. N84/I/16 (part)

41 Any physical quantity which varies with temperature can, in theory, be used to measure temperature. Three such quantities are – the volume of a sample of water, the resistance of a platinum wire and the resistance of a sample of silicon. The table gives the values of these quantities at different temperatures.

Temperature /°C	*Volume of water*/cm³	*Resistance of platinum*/Ω	*Resistance of silicon*/Ω
0	3.47	5.26	2800
8	3.47	5.41	2710
30	3.49	5.84	2310
50	3.52	6.22	1800
80	3.58	6.80	620
100	3.63	7.19	72

Use data from this table where necessary to respond to parts *(b)*, *(c)*, *(d)*, *(e)*, *(f)* which follow.

(b) What advantage would be gained by using a quantity which varies linearly with thermodynamic temperature? [1]

(c) Give one advantage and one disadvantage of using the variation in the resistance of a sample of silicon. [2]

(d) In what way does the table make it clear that water is unsuitable as a thermometric liquid? [1]

(e) A constant α, called the temperature coefficient of resistance, is defined by the equation

$$R_t = R_0 (1 + \alpha t)$$

where R_t is the resistance of a wire at t °C, R_0 is the resistance of the wire at 0 °C and t is the Celsius temperature. Find the average value of α for the platinum wire between 0 °C and 100 °C. [3]

(f) A microbiologist needs accurate measurements of a temperature which varies between 90 °C and 91 °C. Which type of thermometer would you advise? Explain your choice. [4] N90/III/5 (part)

42 *(a)* Explain how a physical property of a substance which varies with temperature may be used for the measurement of temperature. [2]

(b) (ii) Discuss the relative advantages and disadvantages of a liquid-in-glass thermometer and a resistance thermometer which may be used in the same temperature range. [7]

(c) A resistance thermometer is placed in a bath of liquid at 0 °C and its resistance is found to be 3740 Ω. At 100 °C, its resistance is 210 Ω. The bath is now cooled until the resistance of the thermometer is 940 Ω.

(i) What is the temperature of the bath, as measured using the resistance thermometer?

(ii) The reading taken at the same time on a mercury-in-glass thermometer placed in the bath is 40 °C. Suggest a reason for the difference between this reading and the value calculated in (c)(i). [3]

(d) (i) What do you understand by the absolute (thermodynamic) scale of temperature?

J94/III/6 (part)

43 *(b)* By reference to thermal energy transfer, explain what is meant by

(i) two bodies having the same temperature,

(ii) body H having a higher temperature than body C. [2]

(c) (i) Briefly describe how a physical property may be used to measure temperature on its empirical centigrade scale.

(ii) Hence explain why two thermometers measuring temperature on their empirical centigrade scales do not agree at all temperatures. [5]

J99/III/2 (part)

44 *(c)* (i) State **two** physical properties which may be used for the measurement of temperature. [2]

(iv) Express 273 K and your value of T from (iii) as temperatures measured on the Celsius scale. [1]

(v) Comment on the statement 'Today the temperature is 40 °C and yesterday it was 20 °C so it is twice as hot today as it was yesterday.' [2]

N2000/III/5 (part)