

Thermal Energy MS

1. B [1]
2. C [1]
3. (a) Any two from:
Air behaves as an ideal gas (1)
Temperature (in the lungs) stays constant (1)
Implication of no change in mass of gas (1) Max 2
- (b) (i) Use of $\rho = m/V$ (1)
Correct answer ($1.3 \times 10^{-4} \text{ kg s}^{-1}$) (1) 2
Example of calculation:
 $m = V \cdot \rho = 2.5 \times 10^{-4} \text{ m}^3 \times 1.2 \text{ kg m}^{-3} = 3 \times 10^{-4} \text{ kg}$
 $\frac{\Delta m}{\Delta t} = 3 \times 10^{-4} \text{ kg} \times \frac{25}{60 \text{ s}} = 1.25 \times 10^{-4} \text{ kg s}^{-1}$
- (ii) Use of $\Delta E = mc\Delta\theta$ (1)
Correct answer (2.2 W) ecf (1) 2
Example of calculation:
 $P = 1.25 \times 10^{-4} \text{ kg s}^{-1} \times 1000 \text{ J kg}^{-1} \text{ K}^{-1} \times (37.6 - 20.0) \text{ K} = 2.2 \text{ W}$ [6]
4. C [1]
5. (a) as ideal gases do not have forces between molecules so no potential energy (2) 2
- (b) use of $pV = NkT$
conversion of T to kelvin and answer = 5.8×10^{22} molecules 2 [4]

6. (a) top row : 17 1 (14) 4 (1)
 bottom row: 8 1 7 2 (1)
 other product – helium (1) 3

(b) The answer must be clear, use an appropriate style and be organised in a logical sequence (QWC)
 dead star / no longer any fusion (1)
 small dense hot / still emitting radiation/light (1)
 consisting of products of fusion such as carbon / oxygen / nitrogen (1) 3

(c) (i) use of $3/2 kT$ (1)
 conversion to eV (1)
 answer [1.3 (keV)] (1) 3

(ii) gravitational force does work on hydrogen (1)
 increases internal energy of gas (1) 2

(d) The answer must be clear, use an appropriate style and be organised in a logical sequence (QWC)
 A standard candle (in astronomical terms) produces a fixed amount of light /luminosity (1)
 Quantity of hydrogen (1)
 and fusion temperature (1) must be similar for various novae. 3

[14]

7. (a) Absolute zero of temperature
 (Temperature at which) pressure / volume (of a gas) is zero. (1)
 OR
 (Temperature at which) the kinetic energy of the molecules is zero) 1

(b) (i) Number of moles show that calculation
 Recall $pV = nRT$ (1)
 Addition of air pressure (1)
 Conversion to kelvin (1)
 Number of moles = 0.52 (mol) (1)
 Reverse calculations using $n = 0.5$ to arrive at one of the other values can score maximum 3
 Example of answer

$$n = \frac{(1.0 + 1.1) \times 10^5 \text{ Pa} \times 5.8 \times 10^{-3} \text{ m}^3}{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times (273 + 10) \text{ K}}$$

$$n = 0.52 \text{ mol}$$
 4

- (ii) Mass of air
 Mass = 1.5×10^{-2} kg (1)
Example of answer
 mass = $0.52 \text{ mol} \times 0.029 \text{ kg mol}^{-1} = 0.015 \text{ kg}$ 1

- (iii) Temperature calculation
 Use of $P_1/T_1 = P_2/T_2$ (1)
 Correct P_2 1.6×10^5 Pa (1)
 Lowest temperature = 216 K (-57°C) (1)
OR
 Use of $pV = nRT$ (must see correct value of R) (1)
 Correct P_2 1.6×10^5 Pa (1)
 Lowest temp 215K – 223K (-58 to -50°C) (1)
 Example of answer

$$T_2 = \frac{((1.0 + 0.6) \times 10^5 \text{ Pa} \times 283 \text{ K})}{2.1 \times 10^5 \text{ Pa}}$$

$$T_2 = 216 \text{ K}$$
 3

[9]

8. (a) Show that heat energy supplied is about 500 W
 Recall of power = energy/time (1)
 Answer to 2 sig figs [470 [W]] [no ue] (1)
 Example of calculation:
 power = energy/time
 $= 1.63 \times 10^5 \text{ J} / 347 \text{ s}$
 $= 470 \text{ W}$ 2

- (b) (i) Show that heat energy gained is about 1×10^5 J
 Use of $\Delta Q = mc\Delta\theta$ (1)
 Correct answer [1.4×10^5 [J]] [no ue] (1)
 Example of calculation:

$$\Delta Q = mc\Delta\theta$$

$$= 0.44 \text{ kg} \times 3800 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1} \times (96^\circ\text{C} - 12^\circ\text{C})$$

$$= 1.4 \times 10^5 \text{ J}$$
 2

(ii) Calculate the time taken to reach 96 °C
 Use of time = energy/power (1)
 Correct answer [300 s] (1)
 Example of calculation:
 time = energy/power
 = $1.4 \times 10^5 \text{ J} / 470 \text{ W}$
 = 299 s 2

(c) (i) Explain why it might take longer
 Heat supplied to milk at a lower rate / expansion on
 mechanism of heat loss / destination of heat lost (1) 1

(ii) Suggest why time the same
 Power calculation includes a heat loss factor / rate of heat gain the
 same as for water / appropriate mechanism to reduce heat loss
 (Allow 1 for heat losses already taken into account when
 warming the water) (1) 1

[8]

9. (a) (i) Meaning of symbols
 • m = mass of a gas molecule
 • $\langle c^2 \rangle$ = mean square speed of gas molecule
 • T = absolute temperature [accept kelvin temperature] 3

(ii) Physical quantity represented
 • (mean) kinetic energy (of a gas molecule) 1

(iii) Calculation of velocity
 • Use of $\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} k T$ with $T = 223 \text{ K}$
 • Correct answer for velocity [410 m s^{-1}]
 Example of calculation:
 $c = \sqrt{(3 \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times 223 \text{ K} / 5.4 \times 10^{-26} \text{ kg})} = 413 \text{ m s}^{-1}$ 2

(b) (i) Obtain expression for escape velocity
 • Idea that total energy must be zero for molecule just to
 escape
 • So, $\frac{1}{2} m v_{\text{esc}}^2 - GMm/r = 0$, leading to required equation 2

- (ii) Show that escape velocity $> 10 \text{ km s}^{-1}$
- Use of $v_{\text{esc}} = \sqrt{(2GM/r)}$ with $r = (6.37 + 0.01) \times 10^6 \text{ m}$
 - Correct answer for escape velocity [11.1 km s^{-1} , at least 2 sig. figs. required]
- Example of calculation:
- $$v_{\text{esc}} = \sqrt{(2GM/r)}$$
- $$v_{\text{esc}} = \sqrt{(2 \times 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 5.98 \times 10^{24} \text{ kg} / (6.37 + 0.10) \times 10^6 \text{ m})}$$
- $$= 1.11 \times 10^4 \text{ (m s}^{-1}\text{)}$$
- $$= 11.1 \text{ (km s}^{-1}\text{)} \quad 2$$
- (iii) Use of graph to explain whether molecules are likely to escape
- Idea that only a tiny fraction of molecules have a very high velocity
 - Any quantitative attempt to compare the r.m.s. velocity with the escape velocity leading to the conclusion that molecules are not likely to escape. e.g. 410 is much less than 11,000
- 2

[12]

10. (a) (i) Reference to a temperature related gas law **(1)**
 [$V/T = \text{constant}$ **or** $p/T = \text{constant}$ **or** $pV/T = \text{constant}$
or $pV = nRT$; just symbols acceptable or word equivalent
 but not Pressure law or Charles' law]
 At absolute zero, $V = \text{zero}$ **or** $p = \text{zero}$ or $pV = \text{zero}$ **(1)** 2
- (ii) temperature **or** at absolute zero the molecules have
 no kinetic energy **(1)**
 [do not accept depends on, is related to etc]
 (implies) at absolute zero molecules stationary **or**
 not moving **or** still **or** speed / rms of molecules is zero **(1)**
 [If particles/atoms used for both statements 1/2] 2
- (b) Kelvin [absolute thermodynamic scale] 1
- (c) (i) Use of $pV = nRT$ **(1)**
 Use of 300 K **(1)**
 $n = 4.0$ moles **(1)**
 mass of air = 0.12 kg **(1)** ecf their n
 [If no temp conversion $n = 45$ moles, mass = 1.3 kg scores 2/4] 4
- Example of answer
 $n = (1.0 \times 10^5 \text{ Pa} \times 0.10 \text{ m}^3) \div (8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 300 \text{ K})$
 $n = 4.0$ moles
 mass of air = 4.0 moles $\times 0.029 \text{ mole kg}^{-1} = 0.12 \text{ kg}$

- (ii) $nT = \text{constant}$ **or** **or** calculation of initial density **(1)**
 correct use of above equations using Kelvin temperatures or calculation of final density **(1)**
 ratio = $3/5$ or 0.6 **(1)** consequent on gaining method marks
 [ratio of 1.7 or $5/3$ could score 2]
 [calculation of new mass in oven = 0.072 kg scores 1]
 [If Kelvin not used in (c)(i) do not penalise here.
 Ratio is 0.12 – again consequent on method marks] 3
 Example of answer
 $227\text{ }^{\circ}\text{C} = 500\text{K}$ $27\text{ }^{\circ}\text{C} = 300\text{ K}$
 $\frac{227}{500} = \frac{300}{T} \Rightarrow T = 300 \div 0.454 = 662\text{ K}$

[12]

11. (a) (i) Volume of gas **(1)**
 amount of gas or mass of gas or number of moles of gas **(1)** 2
- (ii) **Suitable diagram** to include following **labelled** items
 (Trapped) mass of gas **(1)**
 method of indirectly heating gas **(1)**
 pressure gauge/reader/scale/mercury manometer **(1)**
 thermometer **(1)**
 [wrong experiment e.g. Boyle's Law 0/4] 4
- (iii) precaution;
 Minimise amount of gas not in water bath, stirring,
 allowing time for gas to reach
 temp, parallax errors,
 ANY ONE
 [not insulating the beaker or the water bath]
 [not repeat readings] 1
- (b) Axes labelled with variables and units **(1)**
 Straight line graph with positive gradient **(1)**
 +ve intercept on pressure axis and meeting temp axis
 at $-273\text{ }^{\circ}\text{C}$ OR graph through origin if Kelvin scale
 used and zero written where axes cross. **(1)**
 [if variables other than p and T used 0/3] 3

[10]

12. (a) (i) Specific heat capacity is the energy required when a kg / unit mass (1)
 undergoes a temp change of 1°C / 1K (1) 2
 OR equation(1 mark) terms defined (1 mark)
 [there must be a reference to a temperature so “energy to raise a kg by 1°C” does not get the 2nd mark.
 This is a definition which should be learnt. Also 2nd mark lost if 1 C or 1°K]
- (ii) It is the sum/total of the molecular/atomic (1)
 Potential and kinetic energies (1) 2
 [not particles, or gravitational potential energy]
 [it is not enough to say it is the KE and PE.....]
- (b) Use of $\Delta E = mc\Delta T$ there must be a temperature (1)
 difference for this mark
 $\Delta T = 50\text{ }^\circ\text{C}$ or K (1)
 Energy = $4.4 \times 10^7\text{ J}$ (1)
 [Ignore any negative signs] 3
 Example of answer
 $\Delta E = 800\text{ kg} \times 1.1 \times 10^3\text{ J kg}^{-1}\text{ K}^{-1} \times 50\text{ }^\circ\text{C}$
 $\Delta E = 4.4 \times 10^7\text{ J}$

[7]

13. (a) Estimate of volume of helium:
 Estimate of temperature at sea level [0 °C – 30 °C] (1)
 Conversion of temperatures to kelvin (1)
 Correct substitution for V in expression $V = 4/3 \pi r^3$ (1)
 Example of calculation:
 $V = 4/3 \pi (105\text{ m})^3$
 $V = 4.8 \times 10^6\text{ m}^3$
 Recall of general gas equation ($pV/T = \text{constant}$) (1)
 Use of general gas equation (1)
 Correct answer [$6 \times 10^3\text{ m}^3 \rightarrow 7 \times 10^3\text{ m}^3$] to 2 s.f. [since estimate] (1) 6
 Example of calculation:
 $V_1 = p_2 / p_1 \times T_1/T_2 \times V_2$
 $V_1 = 1/1000 \times 293/213 \times 4.8 \times 10^6\text{ m}^3$
 $V_1 = 6.7 \times 10^3\text{ m}^3$

- (b) Labelling of graph:
 Graph with lower peak labelled “sea level” (1)
 At sea level, temperature is higher, so average K.E. of molecules is higher (1) 2

[8]

14. Gas laws

- (a) Boyle’s law
 Uses $pV = \text{constant}$ (1)
 See $V_2 = 15$ or $(20 - 5) \text{ cm}^3$ (1)
 Pressure = $267/270 \times 10^3 \text{ Pa /Nm}^{-2}$ (1) 3
 Example of answer
 $p_1V_1 = p_2V_2$
 $p_2 = 200 \times 10^3 \text{ Pa} \times 20 \text{ cm}^3 \div 15 \text{ cm}^3$
 $p_2 = 266667 \text{ Pa}$

- (b) Force
 Uses $F = pA$ (1)
 15.8/16.0 N (1) 2
 Example of answer
 $F = 200 \times 10^3 \text{ Pa} \times 7.9 \times 10^{-5} \text{ m}^2$
 $F = 15.8 \text{ N}$

- (c) (i) Pressure law
 Uses $p/T = \text{constant}$ Kelvin or Celsius. (1)
 At least one conversion to Kelvin (295K or 308K) (1)
 $209 \times 10^3 \text{ Nm}^{-2}/\text{Pa}$ (1) 3
 Example of answer
 $p_1/T_1 = p_2/T_2$
 $p_2 = 200 \times 10^3 \text{ Pa} \times 308 \text{ K} \div 295 \text{ K}$
 $p_2 = 208813 \text{ Pa}$

- (ii) Graph
 Curve reasonably similar to one given (1)
 Curve above first. (no ecf for their p_2 less than p_1) (1) 2

[10]

15. (a) Mention of natural frequency (of water molecules) (1)
 At f_0 there is a large/increased **amplitude** (1)
 and hence max energy transfer / max power transfer / max efficiency / max heating (1) 3

- (b) $(1.2 \text{ kg})(3200 \text{ J kg}^{-1} \text{ K}^{-1})(75 \text{ K})$ seen (1)
 $\Rightarrow 288 \text{ kJ}$
 + 600 s to give a power in W [$\Rightarrow 480 \text{ W}$] (1)
 Efficiency $480 \text{ W e.c.f} \div 800 \text{ W} [= 60\%]$ (1)
- There will be heat/energy/power losses from the meat/to the surroundings or water evaporation needs LHV or water evaporation leaves fewer molecules to vibrate

4

[7]

16. (a) Diagram of apparatus

- Trapped gas/ fixed mass of gas with fixed volume (1)
- Pressure gauge/U-tube or mercury/Pressure sensor (1)
- Water bath completely surrounding gas (1)
- Thermometer in water bath or gas /Temperature sensor (1)
 [Boyle's law apparatus 0/4]

4

(b) Method

Record pressure and temperature (1)
 for a range of temperatures/ every x K deg C or min, due to heating (1)

Processing results

Plot graph of p against T (1)
 for temp in Kelvin straight line through origin (1)
 OR
 Calculate p/T average (1)
 and show it is constant for Kelvin temperatures (1)

QOWC (1)

5

(c) Precaution

- Stir water (1)
- Remove energy and await steady temperatures (1)
- Wide range of readings/extend range by use of ice bath (1)
- Eye level with mercury meniscus (1)
- Short/thin tube between gauge and sensor (1)

max 1

[10]

17. Calculation of energy provided by people in one second

$$\begin{aligned} E &= Pt \\ &= 27 \times 80 \text{ W} \times 1 \text{ s} \\ &= 2160 \text{ J [Accept J or W or J s}^{-1}\text{]} \text{ (1)} \end{aligned} \quad 1$$

Show that temperature might rise by about 7 °C

$$\text{Heat generated} = Pt = 2160 \text{ J s}^{-1} \times 40 \times 60 \text{ s} = 5\,184\,000 \text{ J [allow e.c.f.]} \text{ (1)}$$

$$\Delta Q = mc\Delta\theta$$

$$5\,184\,000 \text{ J} = 740 \text{ kg} \times 960 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1} \times \Delta\theta \text{ [Substitution]} \text{ (1)}$$

$$\Delta\theta = 5\,184\,000 \text{ J} \div (740 \text{ kg} \times 960 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}) \text{ (1)} \quad 3$$

$$= 7.3^\circ\text{C [Noe]} \text{ (1)}$$

Explanation of whether actual difference is more or less than answer

Less due to heat loss ... (1)

... through windows /draughts / walls / to contents ... (1) 2

[Allow more due to heat gained (1) from valid source (1)]

That air must be exchanged at about 0.3 kg s⁻¹

$$m = \Delta Q \div c\Delta\theta$$

$$= 2160 \text{ J} \div (960 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1} \times 8 \text{ }^\circ\text{C}) \text{ [Substitution]} \text{ (1)}$$

$$= 0.28 \text{ kg s}^{-1} \text{ [No ue]} \text{ (1)} \quad 2$$

Calculation of time to exchange air

$$740 \text{ kg} \div 0.28 \text{ kg s}^{-1}$$

$$= 2640 \text{ s OR } 44 \text{ minutes (1)} \quad 1$$

[9]

18. (a) (i) Graph

Attempt to find gradient at start of graph ie over 11°C rise or less (1)

Value calculated with units in K s⁻¹ / K min⁻¹ / °C s⁻¹ / °C min⁻¹

Range 0.07 – 0.18 K s⁻¹ or 4.4 – 11.0 K min⁻¹ (1) 2

(ii) Power of heater

Formula $\Delta Q/\Delta t = mc\Delta T/\Delta t$ used (1)

Converts g to kg (1)

Value for rate within acceptable range 18 – 50 W (1) 3

or 1100 – 3000 J min⁻¹

[no ecf from gradient]

(b) Heating process
 (rate of) energy lost to the surroundings OR due to evaporation[do (1)
 not credit boiling] (1) 2
 approaches (rate of) energy supply OR increases with temperature difference.

(c) Graph
 (i) Curve of reducing gradient starting at 20 °C, 0 s (1)
 initially below given graph (consequential mark) (1) 2
 (ii) Explanation
 Reference of need to heat mug (1)
 Hence reduced rate of temperature rise [consequential mark] (1)
 Reference to insulating properties of mug (1) Max 2

[11]

19. (i) Lead shot loses g.p.e. (which becomes k.e.) (1)
 (which becomes/lost to/transfers to) internal (1) 2
 energy/heat
 (ii) Use of $60 mg\Delta h$ [allow between 0.70 m and 0.80 m] (1)
 Use of $mc\Delta\theta/ mc\Delta T$ (1)
 $= 3.6 \text{ K} [\Rightarrow 3.2 \text{ K}] / 3.6 \text{ }^\circ\text{C}$ (1) 3
 (iii) Expect ΔT to be less (1)
 Any 2 of: Tube/plastic warms up; cork/air warms up;
 because lead falls < 80 cm; energy lost to
 surroundings/tube/cork/air ; poor thermal contact with
 thermocouple (1) (1) 3
 (iv) As m cancels / mass does not matter (1)
 but as c is higher (1)
 ΔT will be lower (1) 3

[11]

20. State energy extracted in one second
 35 000 J or 35 kJ [accept J s^{-1} or kJ s^{-1}] (1) 1

Calculate mass of water which flows through system in one second

In one second, $\Delta Q = mc\Delta\theta$

$35\,000\text{ J} = m \times 4200\text{ J kg}^{-1}\text{ K}^{-1} \times 5\text{ K}$ – substitution [ecf] (1)

$m = 35\,000\text{ J} \div (4200\text{ J kg}^{-1}\text{ K}^{-1} \times 5\text{ K})$ – rearrangement (1)

$m = 1.7\text{ kg}$ [accept kg s^{-1}] (1) 3

Give reason for use of solar cells

e.g. cooling needed most during the day or at sunny times of year/
 reduces use of non-renewable resources/uses renewable source/
 reduces production of greenhouse gases/low power/doesn't need
 much energy

cost arguments must explain long term savings [high start up costs
 but low running costs]

[do not accept “environmentally friendly” unqualified] (1) 1

[5]

21. Relationship
 Interpretation of line passing through origin i.e. direct proportionality OR
 inverse proportionality (1)
 between appropriate quantities (1) 2

[Comment that: as $p \uparrow$, $V \downarrow$ / as $p \uparrow$, $1/V \downarrow$ / p times V is constant,
 scores 1 mark only]

Sketch graph

A line with negative gradient (1)

Concave curve [must not touch either axis or continue parallel to axes] (1) 2

Units of pV

$\text{Nm}^{-2} \times \text{m}^3$ [or correct more complex version] (1)

$\text{Nm} = \text{J}$ (1) 2

Explanation

Quality of written communication (1) 1

Any four from the following:

- molecules collide with walls of container
- molecules undergo a change of direction/momentum
- force is rate of change of momentum
- pressure = $\frac{\text{force}}{\text{area}}$ (1) (1) (1)
- large number of molecules hence pressure same/constant (1)

Max 4

[11]

22. Diagram

To include

- lagging
- clock or top pan balance
- variable supply/rheostat + supply OR joulemeter + supply
- V and A correct OR joulemeter parallel to supply (1) (1) (1)

Max 3

Measurements

Mass of aluminium (m) (1)

Initial and final temperature (θ_1, θ_2) (1) 2

EITHER

Current (I) and p.d. (V) (1)

Time (t) that current flows (1)

OR

Initial joulemeter reading (1)

Final joulemeter reading (1) 2

Use of measurements

EITHER

Find temperature rise

Rearranged equation $C = \frac{VIt}{m\Delta\theta}$ OR equivalent (1)

OR

Plot graph $\theta \rightarrow t$ (1)

$$C = \frac{VI}{m \text{ gradient}} \quad (1)$$

Any one assumption (1)

Assume no heat losses to surroundings OR heater completely within block

OR heater 100% efficient

OR Good thermal contact between heater and block OR temperature of block uniform throughout OR stop/start time of clock and heater are the same

[10]

23. Definition of specific heat capacity

Energy (needed) 1

(per) unit mass/kg) 1

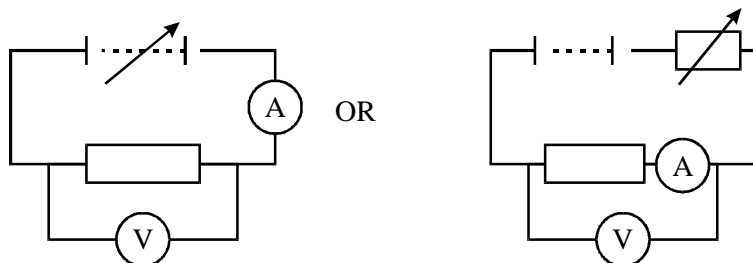
(per) unit temperature change/ °C / K)

OR

Correct formula [does not need to be rearranged] 1

with correctly defined symbols 1

Circuit diagrams



Accept voltmeter across heater and ammeter as well as voltmeter across heater only

Means of varying p.d./current 1

Voltmeter in parallel with a resistor symbol 1

Ammeter in series with any representation of heater 1

Other apparatus

• (Top pan) balance / scales 1

• Stopwatch / timer / clock 1

Explanation

Energy/heat loss to surroundings/air/bench

OR

$mc\Delta\theta + \Delta Q = VIt$ or equivalent in words (e.g. student ignores energy loss in calculations)

OR

$mc\Delta T + \Delta Q = VIt$ or equivalent words 1

Modifications

Any two from

- Use of insulation around block
 - Ensure all of heater is within block
 - Grease heater/thermometer
- 2

[10]

24. Specific heat capacity calculation

$$c = \frac{\Delta Q}{m\Delta\theta} = \frac{860 \times 10^3 \text{ J}}{1.4 \text{ kg} \times (750 - 22) \text{ }^\circ\text{C}}$$

$$c = 844 \text{ (J kg}^{-1} \text{ K}^{-1}/^\circ\text{C}^{-1}\text{)}$$

Conversion to joule $\times 10^3$ 1

Subtraction of temperature 1

Answer 1

[3]

25. Shape of graph

(Temperature) rises more rapidly at first then less rapidly (1)

Heat is lost to the surroundings more quickly as temperature rises (1) 2

Initial rate of temperature rise

Draw tangent at $t = 0 \text{ s}$ (1)

Use a gradient starting at 0 s , 16 to $16.25 \text{ }^\circ\text{C}$ (1)

$$\text{Rate} = (30 \text{ }^\circ\text{C} - 16 \text{ }^\circ\text{C}) \div 1300 \text{ s}$$

$$= 0.011 \text{ }^\circ\text{Cs}^{-1} \text{ [No u.e.] (1)} \quad 3$$

Maximum thermal energy gained in one second

$$AQ = mc\Delta T$$

$$= 0.13 \text{ kg} \times 4200 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1} \times 0.011^\circ\text{C} \text{ (1)}$$

$$\text{Energy gained per second} = 6.0 \text{ J [Accept J, W or J s}^{-1}\text{]} \text{ (1)}$$

2

Efficiency calculation

$$\text{Initial energy input per second} = 0.015 \text{ m}^2 \times 500 \text{ W m}^{-2}$$

$$= 7.5 \text{ J s}^{-1} \text{ (1)}$$

Efficiency = useful energy (or power) output \div energy (or power) input $\times 100\%$

$$= (6.0 \text{ J s}^{-1} \div 7.5 \text{ J s}^{-1}) \times 100\% \text{ (1)}$$

$$= 80\% \text{ OR } 0.8 \text{ OR } 4/5 \text{ (1)}$$

3

Effect of water spillage

Lower mass or heat energy gained by water over-calculated (1)

Calculated efficiency higher than actual efficiency (1)

OR

Air in hose insulates, so less heat absorbed than with no air (1)

Calculated efficiency less than if no water spillage (1)

2

[12]

26. Graph illustrates

$$p_1V_1 = p_2V_2 / pV = \text{constant} / p \propto \frac{1}{V} / p = \frac{\text{constant}}{V} \text{ (1)}$$

1

Pressure of trapped air

(i) $1.20 \times 10^5 \text{ Pa}$ (1)

(ii) $0.80 \times 10^5 \text{ Pa}$ (1)

2

Length of column

$$(0.80 \times 10^5 \text{ Pa} \times 24.0 \text{ cm}) = (1.2 \times 10^5 \text{ Pa} \times L)$$

$$L = 16.0 \text{ cm} \text{ [Accept } 0.16 \text{ m]}$$

See one of their pressures $\times L/24$ (1)

Their upright pressure $\times L =$ their inverted pressure $\times 24$ (1)

Answer $L = 16 \text{ cm}$ (1)

3

Assumption about the dry air

Constant temperature (1)

1

[7]

27. Calculation of energy to heat water

$$\Delta E = mc\Delta \theta$$

$$= 0.2 \text{ kg} \times 4200 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1} \text{ (1)}$$

$$\times (75 \text{ }^\circ\text{C} - 22 \text{ }^\circ\text{C}) \text{ (1)}$$

[i.e. subst mc (1) subst $\Delta \theta$ (1)]

$$= 44\,500 \text{ J (1)}$$

3

Calculation of maximum thermal energy from heater

$$\Delta E = P\Delta t$$

$$\text{OR } \Delta E = 2500 \text{ W} \times 6 \text{ s (1)}$$

$$15\,000 \text{ J (1)}$$

2

Explanation of which suggestion) most likely to be correct

Reservoir, as heater supplies insufficient energy in 6 s [ecf] (1)

1

Effect of heat losses

More energy would be required (1)

1

[7]

28. Volume of bubbles in squashed cup

Recall of $pV = nRT$ (1)

OR pV constant

$$\therefore V_{\text{new}} = p_{\text{old}} \times V_{\text{old}} / p_{\text{new}} \text{ (1)}$$

$$1 \times 10^5 \text{ Pa} \times 7 \times 10^{-5} \text{ m}^3 / 3.5 \times 10^7 \text{ Pa}$$

$$= 2.0 \times 10^{-7} \text{ m}^3 \text{ (1)}$$

3

Assumption

Example of valid assumption: temperature remains constant, air is not an ideal gas, no air escapes (so n constant) (1)

1

Percentage change in average kinetic energy

T changes from 298 K to 283 K (1)

Mean KE $\propto T$

$$\text{so percentage change in mean KE} = (298 - 283) \times 100 / 298 \text{ 5\% (1)}$$

3

[7]

29. Equation

Recall of $pV = nRT$

1

Moles of air

Estimate of temperature ≈ 20 °C [Range 0 – 39] (1)

Use of equation, including conversion of temperature to K AND sensible volume (1)

$$\text{Evaluation: } n = pV/RT = 1.0 \times 10^5 \text{ Pa} \times 20 \times 10^{-6} \text{ m}^3 / 8.31 \times 293$$

$$= 8 \times 10^{-4} \text{ (1)}$$

3

Volume of bubble

($V \propto T$ since p and n constant) (1)

so volume smaller (1)

1

[5]

30. Variables:

Temperature (of gas) (1)

Amount of gas/mass of gas/number of molecules or moles (1)

2

Diagram to include any three of the following:

- trapped gas/fixed mass of gas (1)
- scale [or see dashed lines] (1)
- method of varying pressure [accept unlabelled syringe] (1)
- measurement of pressure [must label pump; accept P.G.] (1) Max 3

[Balloons drawn – no marks

Any unworkable apparatus – 1 max i.e. e.o.p.

Accept standard apparatus/syringes with pressure gauge/masses on moveable pistons.

Ignore water baths.

Heating experiment scores zero.]

Results:

Reference to finding volume from their measurements

[Accept *volume* scale labelled on diagram] (1)

Label axes (1)

2

e.g. $P \rightarrow 1/V$ or $V \rightarrow 1/P$: [Accept $p \approx 1/L$ where L has been identified.

Ignore unit errors on graph]

[7]

31. Show that the energy supplied heating milk is about 60 000 J:

$$E = Pt \text{ OR } = 140 \text{ W} \times 420 \text{ s} \text{ (1)}$$

$$= 59\,000 \text{ J [No u.e.]} \text{ (1)}$$

2

Calculation of thermal energy transferred to milk:

$$E = mc\Delta T$$

$$= 0.2 \text{ kg} \times 3900 \text{ J kg}^{-1} \text{ K}^{-1} \times (38.5 - 13) \text{ (*) K (1)}$$

$$[(*)\text{Allow a different recognisable temp. change for this mark only}] = 19\,900 \text{ J (1)}$$

2

-

Calculation of efficiency:

$$\text{Efficiency} = (\text{useful energy output} / \text{total energy input}) \times 100\%$$

$$= (19\,900 \text{ J} \div 58\,800 \text{ J}) \times 100\% \text{ [Allow e.c.f.]} \text{ (1)}$$

$$= 34\% \text{ [Accept fraction e.g. 0.34]} \text{ (1)}$$

2

Explanation of increase in efficiency:

Surrounding water must also be heated / only heating milk

[Not just heat lost to the surroundings] 1

Explanation of preference for method:

e.g. slower / more gradual temperature increase / easier to control

/ hygiene – keeps milk sterile / more uniform heating /

bottle at correct temperature also

[Do not accept prevents overheating / milk would be too hot.] 1

[8]

32. Sketch graph showing:

p decreasing as V increases [Accept straight line] (1)

Smooth curve, asymptotic to both axes [Not touching or going to touch] (1)
2

Explanation of shape of graph:

As V increases:

packing density of the molecules decreases

OR molecules travel further between collisions (1)

[Look for change in molecular spacing]

Collision (rate) with walls decreases OR change in number of collisions with walls [Ignore reference to intermolecular collisions] (1)
2

How to calculate pressure of air in the syringe:

[NB Not gauges/manometers/ pV method]

Weight (of mass) \div area of piston [no need for Xle] (1)

plus atmospheric pressure (1)

[Penalise if wrong area] 2

Suggested possible source of error:

Any *one* from:

- temperature not constant
- leakage of air OR mass of gas not constant
- weight of piston not included
- friction

(1)

1

[Not non-uniformity of tube/dead space]

[7]

33. $\rho = Nm/V$ (1)

1

$$p = 2/3 (N/V) \frac{1}{2} m \langle c^2 \rangle / \langle c^2 \rangle \propto \text{k.e.} / m \langle c^2 \rangle \propto \text{k.e.} \quad (1)$$

[Full backwards argument can get 1 / 2; full qualitative argument scores 1 / 2]

$$\text{k.e. (or } \frac{1}{2} m \langle c^2 \rangle \text{ or } \langle c^2 \rangle) \propto T, \therefore p \propto T \quad (1)$$

2

V constant (1)

N constant / for fixed mass / fixed number of moles [Not fixed amount] (1)

[Near ideal conditions, specified, can replace one of the above]

[Fixed density, 1 mark]

2

See (273, 308) or 404 (1)

Use $P_1/T_1 = P_2/T_2$ (kelvin temp) (1)

$$= 456 \text{ kPa} \quad (1)$$

[355 kPa gets 3 marks]

[303 kPa \rightarrow 342 kPa, 101 kPa \rightarrow 114 kPa gets 2 marks]

3

[8]

34. Calculation of air pressure at 100 °C:

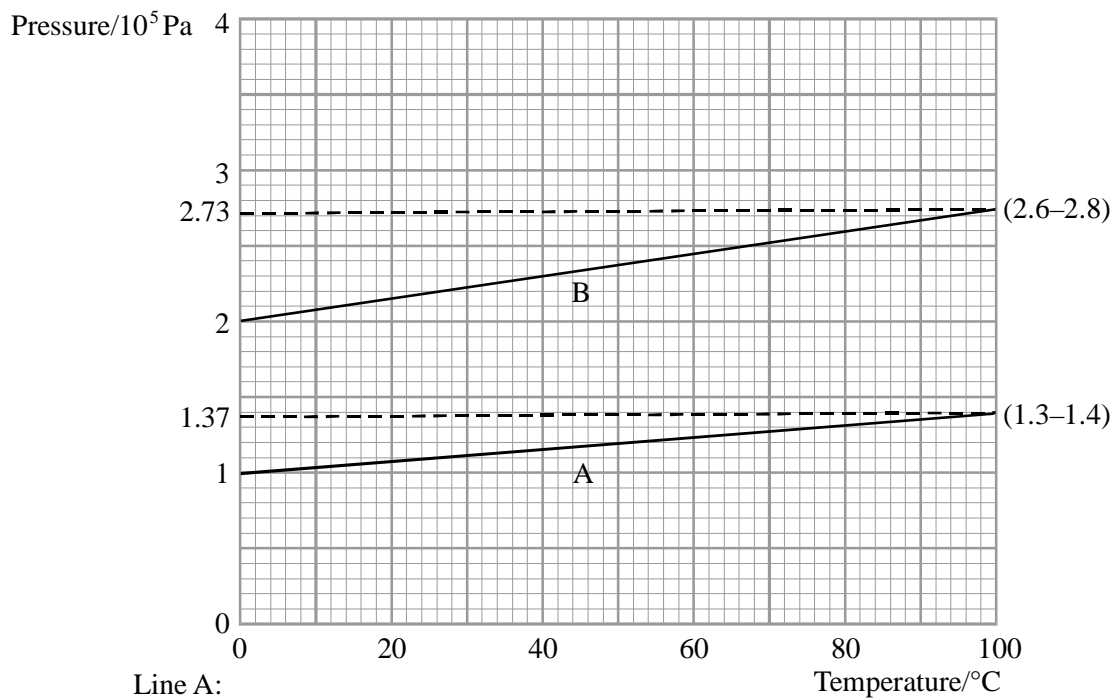
$$\text{Pressure} = 1.00 \times 10^5 \text{ Pa} \times 373 \text{ K} / 273 \text{ K} \quad (1)$$

[If T in °C $\rightarrow 0/2$]

$$= 1.37 \times 10^5 \text{ Pa} / \text{N m}^{-2} \quad (1)$$

2

Graphs to show how air pressure varies with temperature (line A) and how different pressure then varies over same temperature range (line B):



Line A:

Any rising straight line (1)

through correct points [e.c.f end point] (1)

2

Line B:

Rising straight line above line A for all its length (1)

through correct points [e.c.f both points] (1)

2

[6]