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 ρ=m/V **(1)**

Correct answer (1.3×10^{-4} kg s^{-1}) **(1)** 2

Example of calculation:

m V.ρ = 2.5×10^{-4} $m^3 \times 1.2kgm^{-3} = 3 \times 10^{-4}$ kg

$$\frac{\Delta m}{\Delta t} = 3 \times 10^{-4} \text{ kg} \times \frac{25}{60s} = 1.25 \times 10^{-4} \text{ kgs}^{-1}$$

(ii) Use of ΔE = mcΔθ **(1)**

Correct answer (2.2 W) ecf **(1)** 2

Example of calculation:

$P = 1.25\times10^{-4}$ kgs^{-1} $\times1000J$ $kg^{-1}K^{-1}$ ×(37.6 – 20.0)K = 2.2W

[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

$$n = \frac{(1.0+1.1)\times10^{5}\ \text{Pa}\times5.8\times10^{-3}\ \text{m}^{3})}{8.31\,\text{J K}^{-1}\ \text{mol}^{-1}\times(273+10)\text{K}}$$

n = 0.52 mol 4

(ii) Mass of air

Mass = 1.5×10^{-2} kg **(1)**

Example of answer

mass = 0.52 mol × 0.029 kg mol^{-1} = 0.015 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 K 3

[9]

8. (a) Show that heat energy supplied at 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 × 105 J/ 347 s
= 470 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:

$\Delta Q = mc\Delta\theta$

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

$= 1.4 \times 10^5$ 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
= 1.4×10^5 J/ 470 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
- $<c^2>$ = 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 $½ m< c^2 > = 3/2 k T$ with T = 223 K
- Correct answer for velocity [410 m s^{-1}]

Example of calculation:

$c = \sqrt{}(3 \times 1.38 \times 10^{-23}$ J $K^{-1} \times 223$ K / 5.4×10^{-26} kg) = 413 m s^{-1} 2

(b) (i) Obtain expression for escape velocity

- Idea that total energy must be zero for molecule just to escape
- So, $½ m v_{esc}^2 - GMm/r = 0$, leading to required equation 2

(ii) Show that escape velocity > 10 km s^{-1}

- Use of *vesc* = √(2G*M*/*r*) with r = (6.37 + 0.01) × 10^6 m
- Correct answer for escape velocity [11.1 km s^{-1}, at least 2 sig. figs. required]

Example of calculation:

v_{esc} = √(2G*M*/*r*)

v_{esc} = √(2 × 6.67 × 10^{-11} N m^2 kg^{-2} × 5.98 × 10^{24} kg /(6.37 + 0.10) × 10^6 m)

= 1.11 × 10^4 (m s^{-1})

= 11.1 (km s^{-1}) 2

(iii) <u>Use of graph to explain whether molecules are likely to escape</u>

- 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*= constant **or** *p*/*T*= constant **or** *pV*/*T* = constant **or** *pV* = *nRT*; just symbols acceptable or word equivalent but not Pressure law or Charles' law]
At absolute zero, *V* = zero **or** *p* = zero or *pV* = 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 × 10^5 Pa × 0.10 m^3) ÷ (8.31 J K^{-1} mol^{-1} × 300 K)

n = 4.0 moles

mass of air = 4.0 moles × 0.029 mole kg^{-1} = 0.12 kg

(ii) nT = 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 °C = 500K 27 °C = 300 K
$_{500}$ $_{300}$ = 300 ÷ 500 = 0.6

[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 °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 <u>temp change</u> 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 <u>sum/total</u> of the molecular/atomic **(1)**
Potential and kinetic energies **(1)**
[not particles, or gravitational potential energy] 2
[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
ΔT = 50 °C or K **(1)**
Energy = 4.4×10^7 J **(1)**
[Ignore any negative signs] 3

Example of answer
$\Delta E = 800 \text{ kg} \times 1.1 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1} \times 50\ °\text{C}$
$\Delta E = 4.4 \times 10^7$ J

[7]

13. (a) <u>Estimate of volume of helium:</u>
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 = 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 = constant **(1)**
See V_2 = 15 or (20 – 5) cm^3 **(1)**
Pressure = 267/270 × 10^3 Pa /Nm^{-2} **(1)** 3

Example of answer
$p_1V_1 = p_2V_2$
$p_2 = 200 \times 10^3$ Pa × 20 cm^3 ÷ 15 cm^3
p_2 = 266667 Pa

(b) Force
Uses $F = pA$ **(1)**
15.8/16.0 N **(1)** 2

Example of answer
F = 200 × 10^3 Pa × 7.9 × 10^{-5} m^2
F = 15.8 N

(c) (i) Pressure law
Uses p/T = constant Kelvin or Celsius. **(1)**
At least one conversion to Kelvin (295K or 308K) **(1)**
209 × 10^3 Nm^{-2}/Pa **(1)** 3

Example of answer
$p_1/T_1 = p_2/T_2$
$p_2 = 200 \times 10^3$ Pa × 308 K ÷ 295 K
p_2 = 208813 Pa

(ii) Graph
Curve reasonably similar to one given **(1)**
Curve above first. (no ecf for their p2 less than p1) **(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 kg)(3200 J kg^{-1} K^{-1})(75 K) seen **(1)**
⇒ 288 kJ
+ 600 s to give a power in W [⇒ 480 W] **(1)**
Efficiency 480 W e.c.f ÷ 800 W [= 60%] **(1)**

There will be heat/energy/power losses from the meat/to the **(1)** 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

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

Show that temperature might rise by about 7 °C

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

$\Delta Q = mc\Delta\theta$

5 184 000 J = 740 kg × 960 J kg^{-1} °C^{-1} × $\Delta\ \theta$ [Substitution] **(1)**

$\Delta\theta$ = 5 184 000 J ÷ (740 kg × 960 J kg^{-1} °C^{-1}) **(1)** 3

= 7.3°C [Noue] **(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 J ÷ (960 J kg^{-1} °C^{-1} × 8 °C) [Substitution] **(1)**

= 0.28 kg s^{-1} [No ue] **(1)** 2

Calculation of time to exchange air

740 kg ÷ 0.28 kg s^{-1}

= 2640 s **OR** 44 minutes **(1)** 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) Heading: 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 K [⇒ 3.2 K] / 3.6 °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 J = m × 4200 J kg^{-1} K^{-1} × 5 K – substitution [ecf] **(1)**

m = 35 000 J ÷ (4200 J kg^{-1} K^{-1} × 5 K) – rearrangement **(1)**

m = 1.7 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↑, V↓ / as p↑, 1/ V↓ / 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

$Nm^{-2} \times m^3$ [or correct more complex version] **(1)**
Nm = 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 θ → *t* **(1)**

$C = \dfrac{VI}{m \text{ gradient}}$ **(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

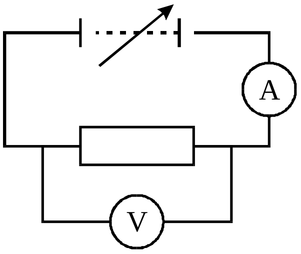
(per) unit mass/kg) 1
(per) unit temperature change/ °C / K)

OR

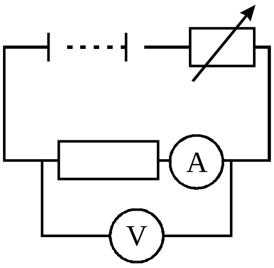
Correct formula [does not need to be rearranged] 1

with correctly defined symbols 1

Circuit diagrams



OR



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

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

OR

$mc\Delta T + \Delta Q = Vlt$ 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

$$c = \frac{\Delta Q}{m\Delta\theta} = \frac{860\times10^3\ \text{J}}{1.4\ \text{kg}\times(750-22)\ °\text{C}}$$

$c = 844$ (J kg^{-1} K^{-1}/°C^{-1})

Conversion to joule × 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 $t = 0$ *s* **(1)**

Use a gradient starting at 0 *s*, 16 to 16.25 °C **(1)**

Rate = (30 °C – 16 °C) ÷ 1300 s

= 0.011°Cs^{-1} [No u.e.] **(1)** 3

Maximum thermal energy gained in one second

$AQ = mc\Delta T$

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

Energy gained per second = 6.0 J [Accept J, W or J s^{-1}] **(1)** 2

Efficiency calculation

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

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

Efficiency = useful energy (or power) output ÷ energy (or power) input × 100%

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

= 80% OR 0.8 OR 4/5 **(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 = constant / $p \propto \frac{1}{V}$ / $p = \frac{cons\tan t}{V}$ **(1)** 1

Pressure of trapped air

(i) 1.20×10^5 Pa **(1)**

(ii) 0.80×10^5 Pa **(1)** 2

Length of column

(0.80×10^5 Pa × 24.0 cm) = (1.2×10^5 Pa × *L*)

L = 16.0cm [Accept 0.16m]

See one of their pressures × *L*/24 **(1)**

Their upright pressure × *L* = their inverted pressure × 24 **(1)**

Answer *L* = 16 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 kg × 4200 J kg.^{-1} $°\text{C}^{-1}$ **(1)**

× (75 °C – 22 °C) **(1)**

[i.e. subst *mc* **(1)** subst Δ θ **(1)**]

= 44 500 J **(1)** 3

Calculation of maximum thermal energy from heater

$\Delta E = P\Delta t$
OR ΔE = 2500 W × 6 s **(1)**

15 000 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

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

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

= 2.0×10^{-7} m^3 **(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 α T

so percentage change in mean KE = (298 – 283) × 100/298 5% **(1)** 3

[7]

29. Equation

Recall of $pV = nRT$ 1

Moles of air

Estimate of temperature ≈20 ^{o}C [Range 0 – 39] **(1)**

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

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

= 8×10^{-4} **(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:

$E = Pt$ OR = 140 W × 420 s **(1)**

= 59 000 J [No u.e.] **(1)** 2

Calculation of thermal energy transferred to milk:

$E = mc\Delta T$

= 0.2 kg × 3900 J kg^{-1} K^{-1} × (38.5 – 13) (*) K **(1)**

[(*)Allow a different recognisable temp. change for this mark only] = 19 900 J **(1)** 2

Calculation of efficiency:

Efficiency = (useful energy output ¸ total energy input) × 100%

= (19 900 J ÷ 58 800 J) × 100% [Allow e.c.f.] **(1)**

= 34% [Accept fraction e.g. 0.34] **(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) ÷ 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

$p = 2/3\ (N/V)\ ½\ m <c^2>$ / $<c^2> \propto$ k.e. / $m <c^2> \propto$ k.e. **(1)**
[Full backwards argument can get 1 / 2; full qualitative argument scores 1 / 2]

k.e. (or $½\ m <c^2>$ or $<c^2>$) $\propto T,\ \therefore p \propto T$ **(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 kPa **(1)**

[355 kPa gets 3 marks]

[303 kPa → 342 kPa, 101 kPa → 114 kPa gets 2 marks] 3

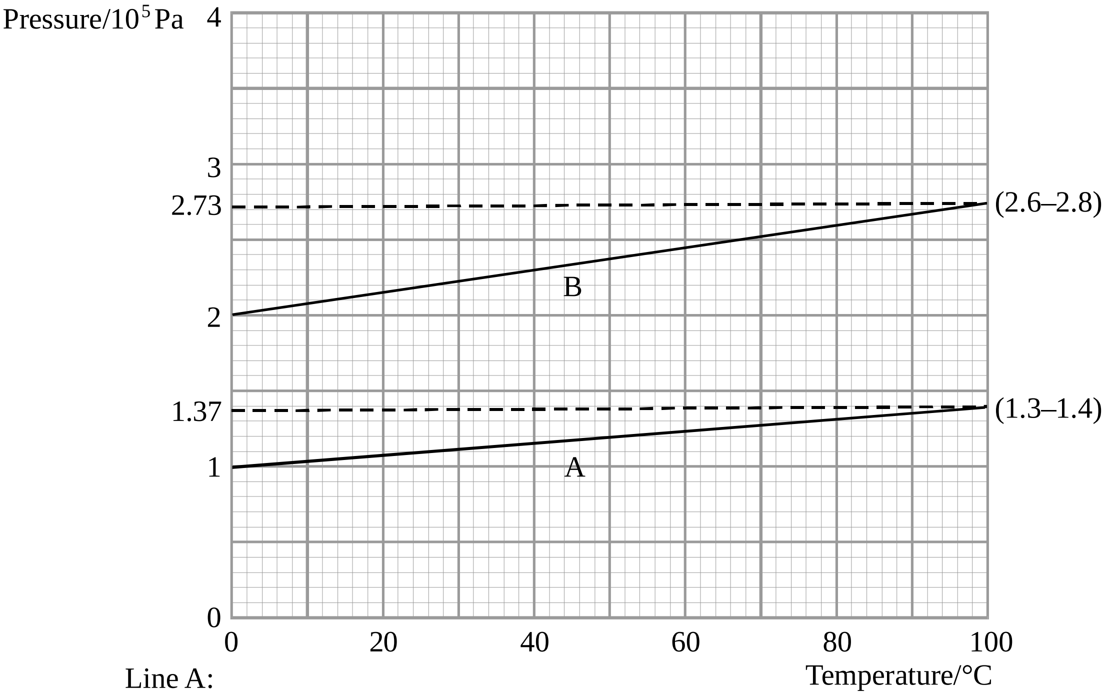
[8]

34. Calculation of air pressure at 100 °C:

Pressure = 1.00×10^5 Pa × 373 K / 273 K **(1)**
[If T in °C → 0/2]

= 1.37×10^5 Pa / N m^{-2} **(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]