# Mark schemes

**1** (a) (it takes) 130 J / this energy to raise (the temperature of) a mass of 1 kg (of lead) by 1 K / 1 °C (without changing its state) ✓

*1 kg can be replaced with unit mass.*

*Marks for 130J or energy.*

*+1 kg or unit mass.*

*+1 K or 1 °C.*

*Condone the use of 1 °K*

**1**

(b) (using $Q = mc\Delta T + ml$)
= 0.75 × 130 × (327.5 – 21) + 0.75 × 23000 ✓
(= 29884 + 17250)
= 47134 ✓
= $4.7 \times 10^4$ (J) ✓

*For the first mark the two terms may appear separately i.e. they do not have to be added.*

*Marks for substitution + answer + 2 sig figs (that can stand alone).*

**3**

**[4]**

**2** (a) The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).

High Level − Good to Excellent
An experiment with results and interpretation must be given leading to the measurement of absolute zero. The student refers to 5 or 6 points given below. However each individual point must stand alone and be clear.*The information presented as a whole should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.*

*6 clear points = 6 marks*

*5 clear points = 5 marks*

**5-6**

Intermediate Level − Modest to Adequate
An experiment must be given and appropriate measurements must be suggested. For 3 marks the type of results expected must be given. 4 marks can only be obtained if the method of obtaining absolute zero is given.*The grammar and spelling may have a few shortcomings but the ideas must be clear.*

*4 clear points = 4 marks*

*3 clear points = 3 marks*

**3-4**

Low Level − Poor to Limited
One mark may be given for any of the six points given below. For 2 marks an experiment must be chosen and some appropriate results suggested even if the details are vague. Any 2 of the six points can be given to get the marks.
*There may be many grammatical and spelling errors and the information may be poorly organised.*

*2 clear points = 2 marks*

*Any one point = 1 mark*

**1-2**

**The description expected in a competent answer should include:**
1. Constant mass of gas (may come from the experiment if it is clear that the gas is trapped) and constant volume (or constant pressure).

*For (point 1) amount / quantity / moles of gas is acceptable.*

2. Record pressure (or volume) for a range of temperatures.(the experiment must involve changing the temperature with pressure or volume being the dependent variable).

*For (point 2) no specific details of the apparatus are needed. Also the temperature recording may not be explicitly stated eg. record the pressure at different temperatures is condoned.*

3. How the temperature is maintained / changed / controlled. (The gas must be heated uniformly by a temperature bath or oven − so not an electric fire or lamp).

4. Describe or show a graph of pressure against temperature (or volume against temperature) that is linear. The linear relationship may come from a diagram / graph or a reference to the Pressure Law or Charles' Law line of best fit is continued on implies a linear graph).

5. Use the results in a graph of pressure against temperature (or volume against temperature) which can be extrapolated to lower temperatures which has zero pressure (or volume) at absolute zero, which is at 0 K or −273 °C (a reference to crossing the temperature axis implies zero pressure or volume).

*For (points 4 and 5) the graphs referred to can use a different variable to pressure or volume but its relationship to V or P must be explicit.*

*In (point 5) the graph can be described or drawn.*

6. Absolute zero is obtained using any gas (provided it is ideal or not at high pressures or close to liquification)
**Or** Absolute temperature is the temperature at which the volume (or pressure or mean kinetic energy of molecules) is zero / or when the particles are not moving.

Discount any points that are vague or unclear

*(Second part of point 6) must be stated not just implied from a graph.*

(b) (i)
- The motion of molecules is random.
- Collisions between molecules (or molecules and the wall of the container) are elastic.
- The time taken for a collision is negligible (compared to the time between collisions).
- Newtonian mechanics apply (or the motion is non-relativistic).
- The effect of gravity is ignored or molecules move in straight lines (at constant speed) between collisions.

✓✓ any two

*If more than 2 answers are given each wrong statement cancels a correct mark.*

**2**

(ii) **Escalate if the numbers used are 4000, 5000 and 6000 giving 25666666 or similar.**

mean square speed
(= $(2000^2 + 3000^2 + 7000^2) / 3 =$
$20.7 \times 10^6$)
$= 2.1 \times 10^7$ ($m^2\ s^{-2}$)

*Common correct answers*

*$20.7 \times 10^6$*

*$21 \times 10^6$*

*$2.07 \times 10^7$*

*$2.1 \times 10^7$*

*20 700 000*

*21 000 000.*

***Possible escalation**.*

**1**

(c) **Escalate if the question and answer line requires a volume instead of a temperature.**

(using meanKE = $3RT / 2N_A$)
$T = 2N_A \times \text{meanKE} / 3R$
$=2 \times 6.02 \times 10^{23} \times 6.6 \times 10^{-21} / 3 \times 8.31$✓
= 320 (K) ✓ (318.8 K)
Or
(meanKE = $3kT / 2$)
$T = 2 \times \text{meanKE} / 3k$
$=2 \times 6.6 \times 10^{-21} / 3 \times 1.38 \times 10^{-23}$ ✓
= 320 (K) ✓ (318.8 K)

*First mark for substitution into an equation.*

*Second mark for answer*

***Possible escalation**.*

*Answer only can gain 2 marks.*

**2**

**[11]**

**3** (a) the number of atoms in 12g of carbon-12
or the number of particles / atoms / molecules in one mole of substance ✓

*not – $N_A$ quoted as a number*

**1**

(b) (i) mean kinetic energy ( = $3 / 2\ kT$) = $3 / 2 \times 1.38 \times 10^{-23} \times (273 + 22)$
$= 6.1 \times 10^{-21}$ (J) ✓

*$6 \times 10^{-21}$ J is not given mark*

**1**

(ii) mass of krypton atom

= 0.084 / 6.02 × $10^{+23}$ ✓

( = 1.4 × $10^{-25}$ kg)

$\overline{c^2}$ ( = 2 × mean kinetic energy / mass

= 2 × 6.1 × $10^{-21}$ / 1.4 × $10^{-25}$)

= 8.7 - 8.8 × $10^4$ ✓

$m^2\ s^{-2}$ or J $kg^{-1}$ ✓

*1st mark is for the substitution which will normally be seen within a larger calculation.*
*allow CE from (i)*
*working must be shown for a CE otherwise full marks can be given for correct answer only*
*no calculation marks if mass has a physics error i.e. no division by $N_A$ note for CE*

*answer = (i) × 1.43 × $10^{25}$*

**3**

(c) (at the same temperature) the mean kinetic energy is the same
or

gases have equal $\frac{1}{2}mc_{rms}^2$
or
mass is inversely proportional to mean square speed / m ∝ 1 $/\overline{c^2}$ ✓

$\overline{c^2}$ or mean square speed of krypton is less ✓

*1st mark requires the word <u>mean / average</u> or equivalent in an algebraic term*

*2nd mark 'It' will be taken to mean krypton. So, 'It is less' can gain a mark*
*allow 'heavier' to mean more massive'*
*allow vague statements like speed is less for 2nd mark but not in the first mark*

**2**

**[7]**

**4** (a) the energy required to change the state of a unit mass of water to steam / gas ✓
when at its boiling point temperature / 100°C / without a change in temperature) ✓

*allow 1 kg in place of unit*
*allow liquid to vapour / gas without reference to water*
*don't allow 'evaporation' in first mark*

**2**

(b) (i) thermal energy given by copper block ( = $mc\Delta T$)

= 0.047 × 390 × (990 – 100)

= $1.6 \times 10^4$ (J) ✓

2 sig figs ✓

*can gain full marks without showing working*
*a negative answer is not given credit*

*sig fig mark stands alone*

**2**

(ii) thermal energy gained by water and copper container

( = $mc\Delta T_{water} + mc\Delta T_{copper}$)

= 0.050 × 4200 × (100 – 84) + 0.020 × 390 × (100 – 84)

or

= 3500 (J) ✓ (3485 J)

available heat energy ( = $1.6 \times 10^4$ – 3500) = $1.3 \times 10^4$ (J) ✓

allow both 12000 J and 13000 J

*allow CE from (i)*
*working must be shown for a CE*
*take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error*
*(3485 is a mark in itself)*
*ignore sign of final answer in CE*
*(many CE's should result in a negative answer)*

**2**

(iii) (using Q = $ml$)

$m = 1.3 \times 10^4 / 2.3 \times 10^6$

= 0.0057 (kg) ✓

Allow 0.006 but not 0.0060 (kg)

*allow CE from (ii)*
*answers between 0.0052 → 0.0057 kg resulting from use of 12000 and 13000 J*

**1**

**[7]**

**5** (a) molecules have negligible volume

collisions are elastic

the gas cannot be liquified

there are no interactions between molecules (except during collisions)

the gas obeys the (ideal) gas law / obeys Boyles law etc.

at all temperatures/pressures

any two lines ✓ ✓

*a gas laws may be given as a formula*

**2**

(b) (i) $n$ (= $PV / RT$) = $1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓

= 130 or 131 mol ✓ (130.5 mol)

**2**

(ii) mass = 130.5 × 0.043 = 5.6 (kg) ✓
(5.61kg)

*allow ecf from bi*

density (= mass / volume) = 5.61 / 0.200 = 28 ✓ (28.1 kg $m^{-3}$)
kg $m^{-3}$ ✓

*a numerical answer without working can gain the first two marks*

**3**

(iii) *($V_2 = P_1 V_1 T_2 / P_2 T_1$)*
*$V_2 = 1.6 \times 10^6 \times .200 \times (273 - 50) / 3.6 \times 10^4 \times (273 + 22)$ or 6.7(2) ($m^3$)* ✓

*allow ecf from bii*

***[reminder must see bii]***
*look out for*

mass remaining = 5.61 × 0.20 / 6.72 = 0.17 (kg) ✓ (0.167 kg)
or
$n = (PV / RT = 3.6 \times 10^4 \times 0.200 / (8.31 \times (273 - 50)) = 3.88(5)$ (mol) ✓

mass remaining = $3.885 \times 4.3 \times 10^{-2} = 0.17$ (kg) ✓
2 sig figs ✓

*any 2 sf answer gets the mark*

**3**

**[10]**

**6** (i) (heat supplied by glass = heat gained by cola)
(use of $m_g c_g \Delta T_g = m_c c_c \Delta T_c$)

*1st mark for RHS or LHS of substituted equation*

$0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓

*2nd mark for 8.4°C*

($210 \times 30 - 210\, t_f = 838\, T_f - 838 \times 3$)
$T_f = 8.4(1)$ (°C) ✓

*Alternatives:*

*8°C is substituted into equation (on either side shown will get mark)* ✓

*resulting in 4620J~4190J* ✓

*or*

*8°C substituted into LHS* ✓ *(produces ΔT = 5.5°C and hence)*

*= 8.5°C ~ 8°C* ✓

*8°C substituted into RHS* ✓

*(produces ΔT = 20°C and hence)*

*= 10°C ~ 8°C* ✓

**2**

(ii) (heat gained by ice = heat lost by glass + heat lost by cola)

*NB correct answer does not necessarily get full marks*

(heat gained by ice = $mc\Delta T + ml$)
heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓
(heat gained by ice = $m \times 346600$)

*3rd mark is only given if the previous 2 marks are awarded*

heat lost by glass + heat lost by cola
= 0.250 × 840 × (8.41 – 3.0) + 0.200 × 4190 × (8.41 – 3.0) ✓
(= 5670 J)

*(especially look for m × 4190 × 3.0)*

*the first two marks are given for the formation of the substituted equation not the calculated values*

$m$ (=5670 / 346600) = 0.016 (kg) ✓

*if 8°C is used the final answer is 0.015 kg*

or (using cola returning to its original temperature)
(heat supplied by glass = heat gained by ice)
(heat gained by glass = 0.250 × 840 × (30.0 – 3.0))
heat gained by glass = 5670 (J) ✓
(heat used by ice = $mc\Delta T + ml$)
heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m$(346600))

$m$ (=5670 / 346600) = 0.016 (kg) ✓

3

**[5]**

**7** **B** **[1]**

**8** **B** **[1]**

**9** **A** **[1]**

**10** **C** **[1]**

# Examiner reports

**1** This question was performed well by a majority of students. The explanation of a specific heat capacity in part (a) was very straightforward. The calculation in part (b) was done well by all but the weakest students even though it contained parts dealing with both specific heat capacity and latent heat. It was in choosing an incorrect number of significant figures that students lost the most marks.

**2** As in previous questions students found explanations difficult but this time they also found some of the calculations difficult. In part (a), the Quality of Written Communication question, it was surprising to come across so many students who appeared to have no knowledge of any experiment concerning gases. This became apparent when their potential experiment was considered. Some thought it feasible to measure the speed of molecules as the temperature was reduced. Others thought that the temperature would reduce uniformly as the pressure was reduced, even reaching absolute zero. A few latched onto an equation such as specific heat that involved temperature and thought they could substitute measured data when the temperature was equal to zero. These students were not an isolated few. Almost a third tackled the experiment in a way that would not work or be impossible to perform. Even students who used a workable idea thought that the experiment could be continued and actually reach absolute zero. The more able students did find this a straightforward task and gave the necessary details in a logical manner but the majority of students did not give their description in a clear fashion and their answers seemed to change direction many times. A very simple error made by many was to quote the temperature of absolute zero as −273 K. The question about assumptions, part (b)(i) was not read carefully by a number of students. In particular they did not respond to the emboldened ‘movement’ in the question. So many answers given were from the usual list of assumptions but they were not given credit here. An example being, ‘molecules have negligible volume’. Even the stronger students sometimes got caught out in this way. As in previous exams some students mistakenly thought that random motion and Brownian motion are one and the same. The calculation of (b)(ii) was not done well by a majority of students. Not because of poor arithmetic but because students did not understand the processing of the term ‘mean square speed’. Some students also had difficulties in part (c) with substituting data into the kinetic ideal gas equation. A large number of students squared the number given in the question for the mean square speed before making the substitution.

**3** A majority of candidates obtained the mark for part (a) by stating it was equal to the number of atoms in one mole of substance. Very few gave the full definition which relates to carbon-12. Many candidates must have been aware of the definition because they tried to incorporate it into what they put down. For example, 'The number of atoms in one mole of carbon-12'. Sometimes the halfway approach went wrong and we saw, 'The number of particles in 1 atom of carbon-12', or similar. There were also a few candidates who took a kinetic theory equation, which had Avogadro constant, which they then rearranged to make the constant the subject. This was not regarded as a definition.

In part (b)(i) was an easy substitution into an easy equation and most candidates scored the mark.

By contrast in (b)(ii) it was only the very best candidates who completed the whole of the question. The main problem was that the majority did not appreciate that the mass of an individual krypton atom was required in the equation for mean kinetic energy. The other surprising difficulty was the unit of mean square speed. Only about a quarter of candidates got this correct.

In part (c) most candidates scored the mark for krypton's mean square speed being less. As expected the most common error in the explanation was to suggest the kinetic energies of both gases are the same rather than having the same means for their kinetic energies.

**4** A majority of candidates only scored one mark in part (a). These candidates either forgot to indicate a unit mass or, as in a majority of cases, they omitted the phrase, 'without a change in temperature', or equivalent. A few had problems in appreciating whether energy was required or whether energy was given out. It was very noticeable that at the lower ability end candidates have a poor vocabulary associated with this area of physics. Phrases like, 'to change water to a gas without changing state', or 'condense water into steam', and others showed a lack of distinction between boiling and evaporation.

The calculation of part (b)(i) did not hold many difficulties for the bulk of the candidates but the significant figure issue did. In part (b)(ii) most candidates were relatively clear how to tackle this question. It was in the detail that errors were made. The most significant was to forget about the copper can, which also gained energy to reach the final temperature. Also at the lower ability end there were many opportunities to make arithmetic errors.

The scores were much better for part (b)(iii) albeit from an error carried forward from part (b)(ii) in many cases. So the use of the latent heat equation is not difficult to grasp for a majority of candidates. The main error was from rounding off incorrectly or making errors in powers of 10 when converting to SI units.

**5** A majority of candidates referred to obeying a gas law in answer to part (a). A second marking point was often missed out, wrong or vague. This is illustrated in the two answers that follow: ‘It has properties of a gas such as Brownian Motion’, and ‘The gas obeys the assumptions of the kinetic theory’.

Parts (b)(i)+(ii) were done well by most. Only a few did not convert the temperature to Kelvin before performing a calculation. Again very few did not know the unit for density.

In part (b)(iii) more than half the candidates could perform the calculation but a significant number of those did not quote the answer to 2 significant figures. Of those missing out on the calculation many did score the first mark but then went wrong by using the wrong density or by not finding the proportion of the gas still in the container.

**6** Candidates found (i) quite difficult for a number of reasons. Some started correctly by equating heat supplied to glass equals heat gained by cola but then they could not make the final temperature the subject of the resulting equation. Others substituted the temperature the wrong way round and used $(3 - T_f)$, which was negative and fudged the arithmetic. As in a previous question candidates did not explain their approach which made it difficult to award partial marks. It was interesting to see some candidates who jumped in too quickly and made an initial mess of the calculation fared better on additional pages when they thought more carefully over the problem.

Part (ii) was also very discriminating. Only the best candidates scored full marks. Good candidates who just missed full marks usually forgot about the 3 degree rise in temperature of the ice after it had melted. Most other candidates were aware of the $mc\Delta T$ and ml equations but then made all manner of different errors.

**7** 15.0% correct