M1.(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) <u>and</u> 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, <u>which is at 0 K or −273 °C</u> (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 <u>must</u> 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
(= $(2000^2 + 3000^2 + 7000^2) / 3$ =
20.7×10^6)
= 2.1×10^7 ($m^2\ s^{-2}$)

Common correct answers

20.7 × 10^6

21 × 10^6

2.07 × 10^7

2.1 × 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 = $3RT / 2N_A$)
$T = 2N_A$ × meanKE / $3R$
=2 × 6.02 ×10^{23} × 6.6 × 10^{-21} / 3 × 8.31✓
= 320 (K) ✓ (318.8 K)
Or
(meanKE = $3kT / 2$)
T = 2 × meanKE / $3k$
=2 × 6.6 × 10^{-21} / 3 × 1.38 × 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]

M2.(a) (i) (Mass change in u=) 1.71× 10^{-3} (u)
or (mass Be−7) – (mass He−3) – (mass He−4) seen with numbers

C1

2.84 × 10^{-30} (kg)
or Converts their mass to kg

Alternative 2nd mark:
*Allow conversion of 1.71 × 10^{-3} (u) to MeV by multiplying by 931 (=1.59 (MeV)) **seen***

C1

Substitution in E = mc^2 *condone their mass <u>difference</u> in this sub but must have correct value for c^2 $(3×10^8)^2$ or $9×10^{16}$*

Alternative 3rd mark:

Allow their MeV converted to joules (× 1.6 × 10^{-13}) ***seen***

C1

2.55 × 10^{-13} (J) to 2.6 × 10^{-13} (J)

Alternative 4th mark:
Allow 2.5 × 10^{-13} (J) for this method

A1

4

(ii) Use of $E=hc/\lambda$ ***ecf***

C1

Correct substitution in rearranged equation with λ *subject* ***ecf***

C1

7.65 × 10^{-13} (m) to 7.8 × 10^{-13} (m) ecf

A1

3

(b) (i) Use of E_p formula:

C1

Correct charges for the nuclei **and** correct powers of 10

C1

2.6(3) × 10^{-13} J

A1

3

(ii) Uses K*E* = 3 / 2 *kT:* ***or*** *halves KE_T, KE= 1.3 × 10^{-13} (J)* ***seen ecf***

C1

Correct substitution of data **and** makes T subject **ecf**
Or uses KE_T value **and** divides T by 2

C1

6.35 × 10^9 (K) or 6.4 × 10^9 (K) or 6.28 × 10^9(K) or 6.3 ×

10^9 (K) **ecf**

A1
3

(c) (i) Deuteron / deuterium / hydrogen−2

B1

Triton / tritium / hydrogen−3

B1
2

(ii) Electrical heating / electrical discharge / inducing a current in plasma / use of e−m radiation / using radio waves (causing charged particles to resonate)

B1
1
[16]

M3.(a) The molecules (continually) move about in random motion ✓

Collisions of molecules with each other and with the walls are elastic ✓

Time in contact is small compared with time between collisions ✓

The molecules move in straight lines between collisions ✓

ANY TWO

Allow reference to 'particles interact according to Newtonian mechanics'

2

(b) Ideas of pressure = F / A and F = rate of change of momentum ✓

Mean KE / rms speed / mean speed of air molecules increases ✓

More collisions with the inside surface of the football each second ✓

Allow reference to 'Greater change in momentum for each collision'

3

(c) Radius = 690 mm / 6.28) = 110 mm or T = 290 K ✓ seen

volume of air = 5.55×10^{-3} m^3 ✓

$n \times 29$(g) = 11.4 (g) ✓ n = 0.392 mol

Use of $pV = nRT = \dfrac{0.392 \times 8.31 \times 290}{5.55 \times 10^{-3}\ \text{m}^3}$ ✓

$p = 1.70 \times 10^5$ Pa ✓

Conclusion: Appropriate comparison of their value for p with the requirement of the rule, ie whether their pressure above 1×10^5 Pa falls within the required band ✓

Allow ecf for their n V and T ✓

6

[11]

M4. D

[1]

M5. (a) (i) $n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$

n = 0.26 mol ✓ (0.257 mol)

1

(ii) $P_2 = \dfrac{T_2}{T_1} \times P_1 = \dfrac{295}{285} \times 3.20 \times 10^5$ ✓

3.31×10^5 Pa ✓ (allow $3.30\text{-}3.35 \times 10^5$ Pa)

3 sig figs ✓ sig fig mark stands alone even with incorrect answer

3

(b) similar -(rapid) **random** motion

- range of speeds

different - **mean** kinetic energy

- root **mean** square speed

- **frequency** of collisions

2

[6]