1. (a) gas that obeys the equation $pV = nRT$ / no forces between molecules;
at all pressures, volumes and temperatures / any other postulate; 2

(b) (i) $pV = nRT$
$20 \times 10^6 \times 2 \times 10^{-2} = n \times 8.3 \times 290$;
$n = 170$ (166); 2 max

(ii) number = $n \times N_A$;
number = $166 \times 6.02 \times 10^{23} = 1.0 \times 10^{26}$; 2

(c) (i) average volume = 2.0×10^{-28} m^3; 1

(ii) average separation $\approx \sqrt[3]{(2.0 \times 10^{-28})}$;
$= 5.8 \times 10^{-10}$ m; 2
Allow solution based on sphere.

[9]

2. (a) the amount of energy / heat required to raise the temperature of a substance / object through 1K / °C; 1

(b) (i) to ensure that the temperature of the metal does not change during the transfer / negligible thermal energy / heat is lost during the transfer; 1
Do not accept metal and water at same temperature.

(ii) to ensure that all parts of the water reach the same temperature; 1

(c) energy lost by metal = $82.7 \times (T - 353)$ J;
energy gained by water = $5.46 \times 10^2 \times 65$ J;
energy gained by calorimeter = 54.6×65 J;
equate energy lost to energy gained to get $T = 825$ K; 4
*Award **[2 max]** if any energy term is missed.*

[7]

3. (a) bubbles rise at constant rate / constant temperature using a thermometer; 1

(b) can check that rate of boiling is constant;
because the two masses should be equal; 2

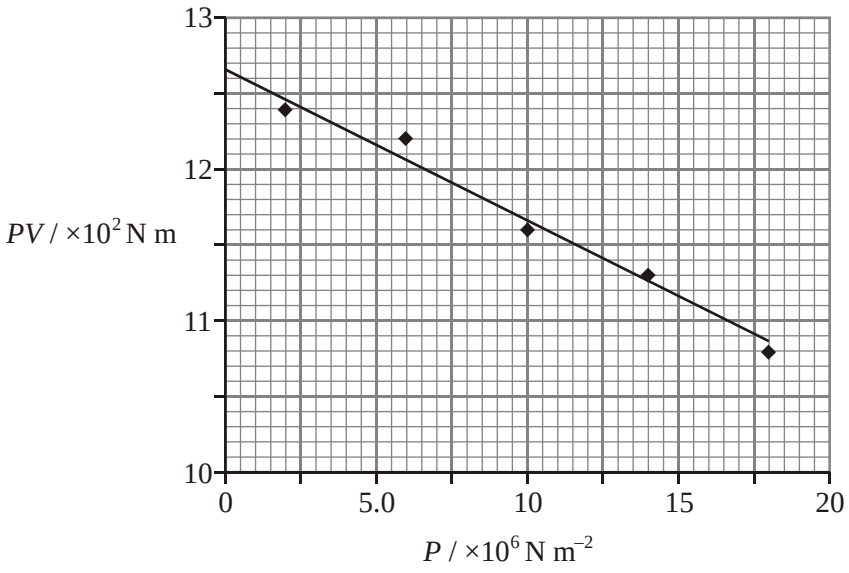
(c) (i) reasonable line drawn; 1

(ii) triangle for gradient with hypotenuse at least half length of line;
some working shown (*e.g.* coordinates used made clear);
answer 12 (W g^{-1}) ± 1; 3

(d) gradient = $\frac{L}{200}$;
$L = 2400$ *allow ecf from (c)(ii)*;
correct unit J g^{-1}; 3

(e) heat energy losses / systematic error;
to the atmosphere / any other detail; 2

[12]



4.

(a) suitable straight-line of best fit; 1

(b) *A* is the intercept on the *y*-axis consistent with line drawn (or by implication);
= 12.6 = 1.3×10^3 Nm – the best fit line should give a 2 SD
value of 1.3×10^3 Nm;
B is the gradient;
some evidence that reasonable values have been used ($y_2 - y_1 > 0.9$, $x_2 - x_1 > 8$);
= $-1.0(\pm 0.1) \times 10^{-5}$; 5

Accept answers based on using two data points on line. Award ***[3 max]*** *if points not on line. Ignore any missing units and do not penalize if minus sign is omitted.*
Award ***[1]*** *for determination of B if only one data point is used.*

(c) $B = 0$; 1

(d) (i) substitute into $PV = A + BP$
$PV = 1300 - (1.0 \times 10^{-5} \times 6.0 \times 10^7)$;
= 700(640 → 760)Nm; 2
= $1.9(\pm 0.5) \times 10^3$ Nm *if BP is added instead of subtracted.*
Award ***[1]*** *for ECF.*

(ii) recognize that the ideal gas value is the intercept on the *y*-axis;
or
from $PV = RT$;
or
= constant A;
difference 600(540 → 660) Nm; 2

(e) error bars constructed on two well separated points;
attempt to draw reasonable extreme graph line/lines;
reasonable estimate of uncertainty;
Accept alternative approach.
total % error for PV = 7%;
7 % of $12.6 \times 10^2 = 0.9 \times 10^2$;
so absolute error = $(\pm 0.9) \times 10^2$ N m; 3

[14]

5. (a) ***[1]*** *for each appropriate and valid point e.g.*
thermal energy is the K.E. of the component particles of an object;
thus measured in joules;
the temperature of an object is a measure how hot something is (it can be used to work out the direction of the natural flow of thermal energy between two objects in thermal contact) / measure of the average K.E. of molecules;
it is measured on a defined scale (Celsius, Kelvin *etc*.); 4 max

(b) (i) correct substitution: energy = power time;
$= 1200 \text{ W} \times (30 \times 60) \text{ s}$;
$= 2.2 \times 10^6 \text{ J}$ 2 max

(ii) use of $E = m\,c\,\Delta\theta$;
to get $\Delta\theta = 2.2 \times 10^6 / (4200 \times 70) \text{ K}$;
$= 7.5 \text{ K}$; 3 max

(c) ***[1]*** *naming each process up to* ***[3 max]***.
convection;
conduction;
radiation;

[1] *for an appropriate (matching) piece of information / outline for each process up to* ***[3 max]***.

e.g. convection is the transfer of thermal energy via bulk movement of a gas due to a change of density;
conduction is transfer of thermal energy via intermolecular collisions;
radiation is the transfer of thermal energy via electromagnetic waves (IR part of the electromagnetic spectrum in this situation) / *OWTTE*; 6 max

(d) (i) energy lost by evaporation = $50\ \% \times 2.2 \times 10^6$ J;
$= 1.1 \times 10^6$ J;
correct substitution into $E = m\,l$
to give mass lost $= 1.1 \times 10^6 \text{ J} / 2.26 \times 10^6 \text{ J kg}^{-1}$
$= 0.487$ kg
$= 487$ g; 3 max

(ii) ***[1 max]*** *for any valid and relevant factor e.g.*
area of skin exposed;
presence or absence of wind;
temperature of air;
humidity of air *etc*.;

[1 max] *for an appropriate and matching explanation e.g.*
increased area means greater total evaporation rate;
presence of wind means greater total evaporation rate;
evaporation rate depends on temperature difference;
increased humidity decreases total evaporation rate *etc*.; 2 max

[20]