A2. (a) satisfies $pV = nRT$ (at all *p*, *V* and *T*) / point molecules / no intermolecular forces; ***[1]***
Allow any other kinetic theory assumption.

(b) (i) the (total random) kinetic energy of the molecules (of the gas); ***[1]***

(ii) the (absolute kelvin) temperature is proportional to/is a measure of the average kinetic energy of the molecules of the gas;
and hence the internal energy is proportional to the temperature (and the total number of molecules in the gas) / $U \propto NT$; ***[2]***
*Do not accept T increases U increases. Award **[0]** for **any** reference to potential energy.*

(c) (i) 2.0×10^5 Pa; ***[1]***

(ii) correct positioning of point on graph; ***[1]***

(iii) concave curve (hyperbola) joining A to B; *(judged by eye)* ***[1]***
Do not check points, general shape of curve only.

A3. (a) the rocket exerts a force on the gases and so the gases exert a force on the rocket / there is a reaction force on rocket from gases / *OWTTE*;
force on the rocket causes the rocket to accelerate; ***[2]***

(b) the net external force on the rocket and gases/system is zero / system is closed/isolated, therefore the total momentum of the system stays the same;
change in momentum of the gases $=$ (–) change in momentum of the rocket; ***[2]***

(c) after 1.0 s momentum of gases $= 1.4 \times \left[7.2 \times 10^3 - v\right]$ N s and momentum of rocket $= (280 - 1.4) \times v$ N s;

application of momentum conservation $\left(\text{to give } v = \dfrac{1.4 \times 7.2 \times 10^3}{280}\right)$;

$36\,\text{m s}^{-1}$; ***[3]***

B3. Part 1 Calorimetry

(a) energy required to increase the temperature by 1 degree; ***[1]***

(b) (i) change in temperature of calorimeter is $6.0\,^{\circ}\mathrm{C}$;
and so $Q = (950 \times 6) = 5.7 \times 10^{3}\ \mathrm{J}$; ***[2]***

(ii) change in temperature of copper block is $72\,^{\circ}\mathrm{C}$;
and so $C = \left(\frac{5.7 \times 10^{3}}{72}\right) = 79\ \mathrm{J\,K^{-1}}$; ***[2]***

(c) the mass of the block; ***[1]***

(d) *Any two suitable suggestions*.
the temperature of the block may not be $100\,^{\circ}\mathrm{C}$;
some boiling water may be transferred to the calorimeter;
the calorimeter is not perfectly insulated; ***[2 max]***

B2. Part 1 Latent heat and specific heat

(a) (i) quantity of thermal energy/heat required to convert unit mass / mass of 1 kg of liquid to vapour/gas;
with no change of temperature / at its boiling point; ***[2]***

(ii) on vaporizing, potential energy of molecules/atoms increases;
on vaporizing, kinetic energy of molecules/atoms does not change;
only change in kinetic energy seen as change in temperature; ***[3]***
The term "vaporizing" or "phase change" should be present at least once to award full marks.

(b) (i) heater, variable resistor and power supply in series;
ammeter in series with heater, voltmeter in parallel with heater; ***[2]***

(ii) $P = VI$ used – not merely quoted;
$I = \frac{80}{9} = 8.9\,\text{A}$; ***[2]***

(iii) idea of $power \times time = mass \times latent\ heat$;
allowance made in equation for heat loss to atmosphere;
$(80 - 35) \times 60 = (1.89 - 0.70) \times L$;
$L = 2300\,\text{J g}^{-1}$; ***[4]***
*Award **[3 max]** for use of two powers and a reference to heat loss to atmosphere/environment to explain the difference in numerical values of L.*
*Award **[2 max]** for use of two powers and taking an average.*
*Award **[1 max]** for use of one power only.*

(c) (i) $\text{mass} = (650 - 350) \times 6 \times 1 = 1800\,\text{g}$; ***[1]***

(ii) $\text{energy} = 1.8 \times 4.2 \times 10^3 \times (100 - 18)$;
$= 6.2 \times 10^5\,\text{J}$ ***[1]***
Award mark for the substitution, not the final answer.

(iii) $\text{cost} = \frac{6.2 \times 10^5 \times 365 \times 3.5}{1.0 \times 10^6}$;
$= 790$ cents; ***[2]***

Part 2 Temperature and thermal energy

(a) property measured at two known temperatures (and at unknown temperature);
(temperature calculated) assuming linear change of property with temperature; ***[2]***
*Award **[1]** for descriptions of constructing a thermometer.*

(b) thermometer absorbs (thermal) energy/heat from the body / has a thermal capacity;
so changes temperature of body;

or

time taken for (thermal) energy/heat to be conducted into thermometer;
so may not be able to follow changing temperature; ***[2]***

(c) (i) quantity of (thermal) energy/heat required to raise temperature of unit mass;
by one degree;

or

$c = \frac{\Delta Q}{m\Delta\theta}$;
with ΔQ, m and $\Delta\theta$ explained; ***[2]***

(ii) $m \times 330$;
$+m \times 4.2 \times 8$;
$= 0.45 \times 4.2 \times 16$;
$m = 0.083\,\text{kg}$; ***[4]***
*Award **[2 max]** for an answer $m = 0.092\,\text{kg}$ – ignoring ice-water.*

(d) (i) *(both are change from liquid → vapour phase)*
evaporation:
occurs at surface of liquid;
occurs at all temperatures;

boiling:
occurs in the body of the liquid;
occurs at one temperature / boiling point; ***[2 max]***

(ii) separation of molecules increases in the change from liquid to vapour phase;
this involves an increase in potential energy;
but temperature observed to change only when kinetic energy changes; ***[3]***

Part 2 Specific latent heat

(a) the amount of (thermal) energy needed to convert a unit mass of a solid substance into a liquid at the melting temperature of the substance / at constant temperature; ***[1]***

(b) (i) $V = 12 \times 3 \times 10^{-2} = 0.36\,\text{m}^3$;
$m = \rho \times V = 900 \times 0.36 = 324$;
$\approx 320\,\text{kg}$ ***[2]***

(ii) $E = PtA = 340 \times 12 \times 6 \times 60 \times 60$;
$= 8.8 \times 10^7$ J (*no marks for answer*) ***[1]***

(iii) mass that can melt with this available energy is
$\dfrac{8.8 \times 10^7}{330 \times 10^3} = 270\,\text{kg}$;
and so not all the ice will melt;

or

energy required to melt ice = $320 \times 330 \times 10^3 = 1.1 \times 10^8$ J;
so not all the ice melts (as this is more than the available energy); ***[2]***
Do not accept answers without justification.

(iv) that all the energy incident on the ice gets absorbed / that no energy gets reflected / no energy gets conducted to the water below; ***[1]***

(c) *Accept any reasonable discussion based on any method of heat transfer e.g.*
the air in contact with the ice is warmer than the rest and so rises;
leaving its place to colder air which in turns warms up as well carrying energy away from the ice;

or

the water/ice surface is warmer than the surroundings;
and so radiates electromagnetic waves losing thermal energy/net transfer by radiation losses;

or

the molecules of ice/water in contact with the air molecules;
transfer energy to them through collisions thus losing thermal energy; ***[2]***

B3. Part 1 Gases and liquids

(a) forces between gas molecules (except during collisions) are much smaller than between liquid molecules;
speed of gas molecules much greater than speed of liquid molecules;
motion/movement of gas molecules is less restricted than that for liquid molecules;
average separation of molecules much greater in a gas than in a liquid; ***[2 max]***

(b) the molecules do not have the same speed / the molecules have different speeds;
the speed of the molecules change each time they collide / the speed of individual molecules is always changing / *OWTTE*; ***[2]***
Accept use of words "kinetic energy" in place of speed.

(c) the energy/heat required to raise/change the temperature of a substance by $1\text{ K}/^{\circ}\text{C}$; ***[1]***

(d) (i) the water is changing phase/boiling / KE of molecules is constant, (PE is changing); ***[1]***

(ii) $\text{time} = 420\,(\text{s})$;
energy supplied $= 300 \times 420$;
$= 4.2 \times 10^3 \times 0.40 \times \Delta\theta$;
to give $\Delta\theta = 75$;
therefore, boiling temperature $\theta = 95\,^{\circ}\text{C}$; ***[5]***

(e) $300 \times 3.0 \times 10^3 = 0.40\,L$;
to give $L = 2.3 \times 10^6\ \text{J kg}^{-1}$; ***[2]***