21 Marking scheme: Worksheet (A2)

1 **a** The atoms in a solid are arranged in a three-dimensional structure. [1]
There are strong attractive forces between the atoms. [1]
The atoms vibrate about their equilibrium positions. [1]

b The atoms in a liquid are more disordered than those in a solid. [1]
There are still attractive electrical forces between molecules but these are weaker than those between similar atoms in a solid. [1]
The atoms in a liquid are free to move around. [1]

c The atoms in a gas move around randomly. [1]
There are virtually no forces between the molecules (except during collisions) because they are much further apart than similar molecules in a liquid. [1]
The atoms of a gas move at high speeds (but no faster than those in a liquid at the same temperature). [1]

2 The atoms move faster [1]
because their mean kinetic energy increases as the temperature is increased. [1]
The atoms still have a random motion. [1]

3 **a** The internal energy of a substance is the sum (of the random distribution) of the kinetic and potential energies of its particles (atoms or molecules). [1]

b There is an increase in the average kinetic energy of the aluminium atoms as they vibrate with larger amplitudes about their equilibrium positions. [1]
The potential energy remains the same because the mean separation between the atoms does not change significantly. [1]
Hence, the internal energy increases because there is an increase in the kinetic energy of the atoms. [1]

c As the metal melts, the mean separation between the atoms increases. [1]
Hence, the electrical potential energy of the atoms increases. [1]
There is no change in the kinetic energy of the atoms because the temperature remains the same. [1]
The internal energy of the metal increases because there is an increase in the electrical potential energy of the atoms. [1]

4 Change in thermal energy = mass × specific heat capacity × change in temperature [1]

5 The specific heat capacity refers to the energy required to change the temperature of a substance. [1]
Specific latent heat of fusion is the energy required to melt a substance; there is no change in temperature as the substance melts. [1]

6 $E = mc\Delta\theta$ [1]
$E = 6.0 \times 10^5 \times 4200 \times (24 - 21)$ [1]
$E = 7.56 \times 10^9\ \text{J} \approx 7.6 \times 10^9\ \text{J}$ [1]

7 $E = mc\Delta\theta$ [1]
$E = 300 \times 10^{-3} \times 490 \times (20 - 300)$ [1]
$E = -4.1 \times 10^4\ \text{J}$ (The minus sign implies energy is released by the cooling metal.) [1]

8 $E = mL_f = 200 \times 10^{-3} \times 3.4 \times 10^5$ [1]

$= 6.8 \times 10^4\ \text{J}$ [1]

9 **a** **i** $T = 273 + 0 = 273$ K [1]
ii $T = 273 + 80 = 353$ K [1]
iii $T = 273 - 120 = 153$ K [1]
b **i** $\theta = 400 - 273 = 127$ °C [1]
ii $\theta = 272 - 273 = -1$ °C [1]
iii $\theta = 3 - 273 = -270$ °C [1]

10 **a** The thermal energy E supplied and the specific heat capacity c remain constant.
The mass m is larger by a factor of 3. [1]
Since $E = mc\Delta\theta$, we have:
$\Delta\theta = \frac{E}{mc}$; $\Delta\theta \propto \frac{1}{m}$ [1]
Therefore $\Delta\theta = \frac{15}{3} = 5.0$ °C [1]
b The thermal energy E supplied is halved but the specific heat capacity c and the mass m remain constant. [1]
Since $E = mc\Delta\theta$, we have:
$\Delta\theta = \frac{E}{mc}$; $\Delta\theta \propto E$ [1]
Therefore $\Delta\theta = \frac{15}{2} = 7.5$ °C [1]

11 **a** Melting point = 600 °C [1]
(There is no change in temperature during change of state.)
b The lead is being heated at a steady rate and therefore the temperature also increases at a steady rate. [1]
c The energy supplied to the lead is used to break the atomic bonds and increase the separation between the atoms of lead (and hence their potential energy increases). [1]
d $E = mc\Delta\theta$ [1]
$E = 200 \times 10^{-3} \times 130 \times (600 - 0)$ [1]
$E = 1.56 \times 10^4$ J $\approx 1.6 \times 10^4$ J [1]
e In a time of 300 s, 1.56×10^4 J of energy is supplied to the lead.
Rate of heating = power
power = $\frac{1.56 \times 10^4}{300}$ [1]
power = 52 W [1]
f Energy supplied = 52 × 100 = 5200 J [1]
$L_f = \frac{\Delta E}{\Delta m} = \frac{5200}{0.2}$ [1]
$= 26\,000$ J kg^{-1} [1]

12 The energy supplied per second is equal to the power of the heater.
In a time of 1 s, water of mass 0.015 kg has its temperature changed from 15 °C to 42 °C. [1]
$E = mc\Delta\theta$ (where E is the energy supplied in 1 s) [1]
$E = 0.015 \times 4200 \times (42 - 15)$ [1]
$E = 1.7 \times 10^3$ J [1]
The power of the heater is therefore 1.7 kW. [1]
(You may use $P = (\frac{m}{t})c\Delta\theta$)

13 The gas does work against atmospheric pressure. [1]
Energy to do this work is taken from the internal energy of the gas. [1]

14 Heat 'lost' by hot water = heat 'gained' by cold water. [1]
$0.3 \times c \times (90 - \theta) = 0.2 \times c \times (\theta - 10)$ [1]
where c is the specific heat capacity of the water and θ is the final temperature.
The actual value of c is not required, since it cancels on both sides of the equation.
Hence:
$0.3 \times (90 - \theta) = 0.2 \times (\theta - 10)$ [1]
$27 - 0.3\theta = 0.2\theta - 2.0$ [1]
$0.5\theta = 29$ so $\theta = 58$ °C [1]

15 Heat 'lost' by metal = heat 'gained' by cold water [1]
$0.075 \times 500 \times (\theta - 48) = 0.2 \times 4200 \times (48 - 18)$ [1]
(θ is the initial temperature of the metal.)
$\theta - 48 = \dfrac{0.2 \times 4200 \times 30}{0.075 \times 500}$ [1]
$\theta - 48 = 672$ [1]
$\theta = 720$ °C [1]

