

92. (a) We recall the sign convention for heat exchange developed in Chapter 19: the value of Q is positive when the system absorbs heat and negative when it releases heat. Thus, in part (a) we have $Q = -300$ kJ, which is used in $Q = c_{\text{liquid}} m \Delta T$ to produce $\Delta T = -18.75$ C° so that the resulting temperature is $T_a = T_0 + \Delta T = 61.25$ °C (“block P ”).
- (b) With $Q = -400$ kJ in $Q = c_{\text{liquid}} m \Delta T$, we find $\Delta T = -25$ C°, yielding $T_b = T_a + \Delta T = 36.25$ °C (“block S ”).
- (c) With $Q = -820$ kJ in $Q = c_{\text{liquid}} m \Delta T$, we find $\Delta T = -51.25$ C°, yielding $T_c = T_b + \Delta T = -15.00$ °C (“block X ”).
- (d) We adapt the change-of-state equation to the sign convention adopted for Q (so that the equation is generally $Q = \pm L m$). With $Q = -820$ kJ in $Q = -L_F m'$, we find $m' = 1.67$ kg, so that not quite half the material has solidified (still in “block X ” at -15.00 °C).
- (e) As a result of part (d), there is $m'' = m - m' = 4.00 - 1.67 = 2.33$ kg of liquid material which remains to solidify before the system may continue lowering temperature (as a solid). With $Q = -670.0$ kJ in $Q = -L_F m'' + c_{\text{solid}} m \Delta T$, we find $\Delta T = -40$ C°, yielding $T_e = T_d + \Delta T = -55.00$ °C (“block BB ”).
- (f) Now the system is absorbing heat: with $Q = 1240.0$ kJ and $\Delta T' = 40$ C° in $Q = c_{\text{solid}} m \Delta T' + L_F m + c_{\text{liquid}} m \Delta T$, we find $\Delta T = 20$ C°, yielding $T_f = T_e + \Delta T' + \Delta T = 5.00$ °C (“block V ”).
- (g) With $Q = 1280$ kJ in $Q = c_{\text{liquid}} m \Delta T$, we find $\Delta T = 80$ C°, yielding $T_g = T_f + \Delta T = 85.00$ °C (“block N ”).
- (h) With $Q = 820.0$ kJ and $\Delta T = 20$ C° in $Q = c_{\text{liquid}} m \Delta T + L_V m'$, we find $m' = 1.00$ kg, so one-fourth of the material has vaporized at $T_h = T_g + \Delta T = 105.0$ °C (“block L ”).
- (i) With $Q = 1000$ kJ in $Q = L_V m''$, we find $m'' = 2.00$ kg, so three-fourths of the material has now vaporized at $T_i = T_h = 105.0$ °C (“block L ”).
- (j) We are careful to interpret the given “Molar mass = 3.000” as that of the element (the single atoms), so that for a diatomic gaseous configuration we must use 6.000 g/mol when converting between mass m and moles n . Note that the temperature has not reached the point where rotational modes are excited, so $C_V = (3/2)R$. In the equation that follows, m''' is the mass (at the end of the preceding step) remaining to vaporize (1.000 kg) and $n = m/(6.000) = 666.7$ mol. With $Q = 583.1$ kJ in $Q = L_V m''' + n C_V \Delta T$, we find $\Delta T = 10$ C°, yielding $T_j = T_i + \Delta T = 115.0$ °C (“block K ”).
- (k) With $Q = 166.2$ kJ in $Q = n C_V \Delta T$, we find $\Delta T = 20$ C°, yielding $T_k = T_j + \Delta T = 135.0$ °C (“block I ”).
- (l) Note that the temperature is now in the range where rotational modes are excited, so $C_V = (5/2)R$. With $Q = 277.0$ kJ in $Q = n C_V \Delta T$, we find $\Delta T = 20$ C°, yielding $T_l = T_k + \Delta T = 155.0$ °C (“block G ”).
- (m) With the temperature in the range where rotational modes are excited *and* expanding at constant pressure, we have $C_p = (7/2)R$. With $Q = 581.7$ kJ in $Q = n C_p \Delta T$, we find $\Delta T = 30$ C°, yielding $T_m = T_l + \Delta T = 185.0$ °C (“block D ”).
- (n) Finally, we are in the temperature range where vibrational modes are excited (and expanding at constant pressure), so that we have $C_p = (9/2)R$. With $Q = 249.3$ kJ in $Q = n C_p \Delta T$, we find $\Delta T = 10$ C°, yielding $T_n = T_m + \Delta T = 195.0$ °C (“block C ”).