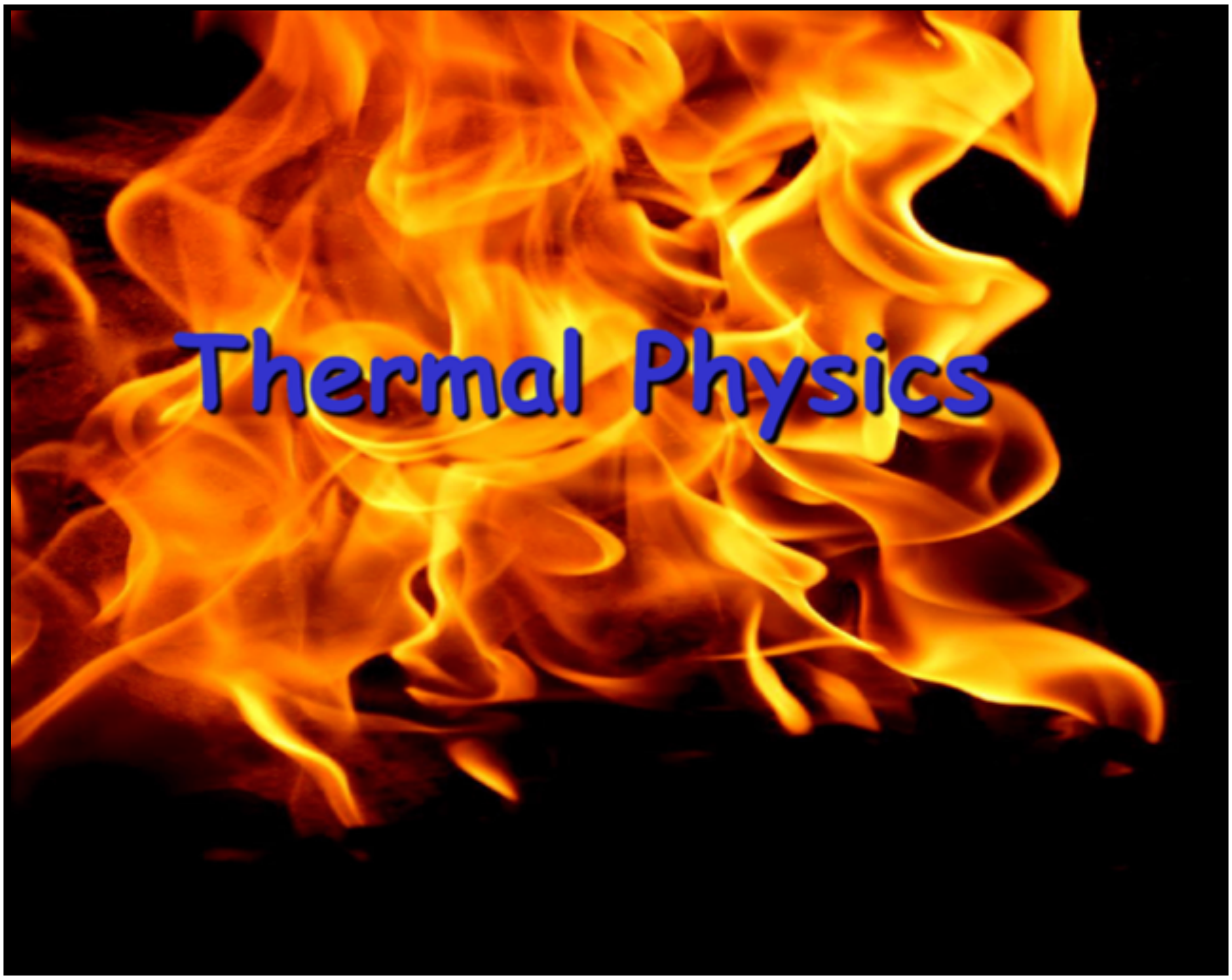


Grading over next 24-48 hrs

$$T_C = \frac{5}{9}(T_F - 32) \qquad K = \frac{3}{2}k_B T$$

$$T_F = \frac{9}{5}T_C + 32 \qquad k_B = 1.38 \times 10^{-23}\ \text{J/K}$$

$$T_K = T_C + 273.15$$

1 BTU (British Thermal Unit) = 1055 J = 252 cal

C: 0°C = freezing water
100°C = boiling

F: 32° = freezing water
212° = boiling

K: 0°K means 0 J of energy (no interaction w/ entire universe)

Change in C will mean exact same change in K

Q: Heat Energy

mass

specific heat

Temp Change (in C or K)

$$\Delta Q = \underbrace{m}_{\text{mass}}\,\underbrace{c}_{\text{specific heat}}\,\Delta T$$

$$\Delta Q = mL_f \qquad\qquad \Delta Q = mL_v$$

$$1 \text{ cal} = 4.186 \text{ J}$$
$$1 \text{ kcal} = 1000 \text{ cal} = 4186 \text{ J}$$
$$1 \text{ Btu} = 778 \text{ ft} \cdot \text{lb} = 252 \text{ cal} = 1055 \text{ J}$$

L_f: Latent Heat of Fusion: amount of energy needed to change the phase of a substance from a solid to a liquid

L_v: Latent Heat of Vaporization: amount of energy needed to change substance from liquid to a gas. (would have to be removed to reverse from gas to liquid) energy to raise 1kg by 1°C

Table 20.1 **Specific Heats of Some Substances at 25°C and Atmospheric Pressure**

Substance	Specific Heat (J/kg · °C)	Substance	Specific Heat (J/kg · °C)
Elemental solids		*Other solids*	
Aluminum	900	Brass	380
Beryllium	1 830	Glass	837
Cadmium	230	Ice (−5°C)	2 090
Copper	387	Marble	860
Germanium	322	Wood	1 700
Gold	129	*Liquids*	
Iron	448	Alcohol (ethyl)	2 400
Lead	128	Mercury	140
Silicon	703	Water (15°C)	4 186
Silver	234	*Gas*	
		Steam (100°C)	2 010

Note: To convert values to units of cal/g · °C, divide by 4 186.

When Temp = melting/feezing point

When Temp = boiling/condensation point

Substance	Normal Melting Point K	Normal Melting Point °C	Heat of Fusion, L_f (J/kg)	Normal Boiling Point K	Normal Boiling Point °C	Heat of Vaporization, L_v (J/kg)
Helium	*	*	*	4.216	−268.93	20.9×10^3
Hydrogen	13.84	−259.31	58.6×10^3	20.26	−252.89	452×10^3
Nitrogen	63.18	−209.97	25.5×10^3	77.34	−195.8	201×10^3
Oxygen	54.36	−218.79	13.8×10^3	90.18	−183.0	213×10^3
Ethanol	159	−114	104.2×10^3	351	78	854×10^3
Mercury	234	−39	11.8×10^3	630	357	272×10^3
Water	273.15	0.00	334×10^3	373.15	100.00	2256×10^3
Sulfur	392	119	38.1×10^3	717.75	444.60	326×10^3
Lead	600.5	327.3	24.5×10^3	2023	1750	871×10^3
Antimony	903.65	630.50	165×10^3	1713	1440	561×10^3
Silver	1233.95	960.80	88.3×10^3	2466	2193	2336×10^3
Gold	1336.15	1063.00	64.5×10^3	2933	2660	1578×10^3
Copper	1356	1083	134×10^3	1460	1187	5069×10^3

Conservation of Energy (Heat Energy)

$$\Sigma Q_i = \Sigma Q_f$$

$$\Delta Q = 0$$

---

with kinetic energy + potential energy

$$K_i + U_i = K_f + U_f + \Delta Q$$

?

During a bout with the flu an 80-kg man ran a fever of 39.0°C (102.2°F) instead of the normal body temperature of 37.0°C (98.6°F). Assuming that the human body is mostly water, how much heat is required to raise his temperature by that amount?

$m = 80\ kg$

$\Delta T = 2°C$

$C_{water} = 4186$

$\Delta Q = mc\Delta T$

$= (80\ kg)(4186\ \frac{J}{kg \cdot °C})(2°C)$

$\Delta Q = 669,760\ J$

Doesn't match lecture @ 28:16

liquid liquid

Suppose that 250 g of water at 85°C is mixed with 95 g of water at 15°C in an insulated container of negligible heat capacity. What is the final temperature?

$\Delta Q = 0$

$\Delta Q = \Delta Q_{hot} + \Delta Q_{cold}$

$T_{final} = \left(\frac{250}{345}\right) 85°C + \left(\frac{95}{345}\right) 15°C$

$= (0.72)\ 85°C + (0.275)\ 15°C$

$= 61.2 + 4.13$

$= 65.33$

$\boxed{T_{final} = 65°C}$

$[(0.25)(4186)(T_f - 85)] + [(0.095)(4186)(T_f - 15)] = \emptyset$

$1046.5\ T_f - 88952 + 397.67 T_f - 5965.05 = 0$

$1444.17\ T_f = 94917.05$

$T_f = 65.7°C$

A camper pours 0.300 kg of coffee, initially in a pot at 70.0°C, into a 0.120-kg aluminum cup initially at 20.0°C. What is the equilibrium temperature? Assume that coffee has the same specific heat as water and that no heat is exchanged with the surroundings.

$$m \quad c \quad \Delta T \qquad m \quad c \quad \Delta T$$

$$[(0.3)(4186)(T_f - 70°c)] + [(0.12)(900)(T_f - 20°c)] = \varnothing$$

$$1255.8\,T_f - 87906 + 108\,T_f - 2160 = \varnothing$$

$$1363.8\,T_f = 90066$$

$$T_f = 66\,°C$$

Homework

You pour 150 g of hot coffee at 85°C into a 210 g glass cup at 22°C. If they come to thermal equilibrium quickly, what is the final temperature? Assume no heat is lost to the surroundings.

$$\Delta Q_{coffee} + \Delta Q_{glass} = \emptyset$$

$$mc\Delta T + mc\Delta T = \emptyset$$

$$\left[(0.15\,kg)(4180\ J/kg\,°C)(T_f - 85°C)\right] + \left[(0.21\,kg)(837\ J/kg\,°C)(T_f - 22°C)\right]$$

$$627\,T_f - 53{,}295 + 175.77\,T_f - 3{,}866.94$$

$$802.77\,T_f = 57{,}161.94$$

$$T_f = 71.2°C$$

A 175 g copper block at 90°C is dropped into an aluminum calorimeter cup initially at 20°C. The calorimeter cup has a mass of 400 g and contains 430 g of water, also at 20°C. What is the final temperature of the system?

$$\Delta Q_{Cu} + \Delta Q_{Al} + \Delta Q_w = \emptyset$$

$$\left[(0.175)(390\ \tfrac{J}{kg\,°C})(T_f - 90°C)\right] + \left[(0.4)(900\ \tfrac{J}{kg\,°C})(T_f - 20)\right] + \left[(0.43)(4186)(T_f - 20)\right] = \emptyset$$

$$\left[68.25\,T_f - 6142.5\right] + \left[360\,T_f - 7200\right] + \left[1799.98\,T_f - 35{,}999.6\right] = \emptyset$$

$$2228.23\,T_f - 49{,}342.1 = \emptyset$$

$$2228.23\,T_f = 49{,}342.1$$

$$T_f = 22.1\ °C$$

$m_{Cu} = 0.175$ kg

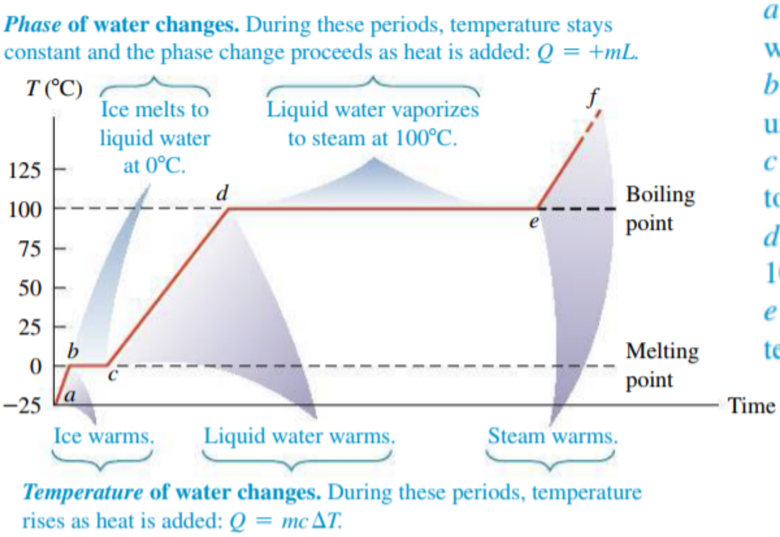
$m_{Al} = 0.4$ kg

$m_w = 0.43$ kg

$c_w = 4186$ J/kg °C

$c_{Al} = 900$ J/kg °C

$c_{Cu} = 390$ J/kg °C



$a \rightarrow b$: Ice initially at −25°C is warmed to 0°C.

$b \rightarrow c$: Temperature remains at 0°C until all ice melts.

$c \rightarrow d$: Water is warmed from 0°C to 100°C.

$d \rightarrow e$: Temperature remains at 100°C until all water vaporizes.

$e \rightarrow f$: Steam is warmed to temperatures above 100°C.

$L_f = 334{,}000 \text{ J/kg}$

How many joules of energy are required to change 100 g of water to steam at 100°C?

$L_v = 2{,}256 \times 10^3$

$\Delta Q = m L_v$

$= 0.1\,(2256 \times 10^3\ J/kg)$

$\Delta Q = 2{,}256 \times 10^2\ J$

$\Delta Q = 225{,}600\ J$

How many joules of energy are removed to change 450 g of liquid iron to a solid at 1808 K? How many calories?

$L_f = 138 \times 10^3\ J/kg$

$\Delta Q = m L_f$

$= 0.45\ \cancel{kg}\,(138 \times 10^3\ J/\cancel{kg})$

$= -62.1 \times 10^3\ J$

$\Delta Q = -62{,}100\ J$

(negative because removing energy from liquid phase to solid phase)

$cal = 62100\ J \cdot \frac{1\ cal}{4.186}$

$\Delta Q = -14{,}835\ cal$

How many joules are required to change one kilogram of ice at -15°C to water at 15°C?

$$\left[m C_{ice} (15°C)\right] + \left[m L_f\right] + \left[m C_{water} (15°C)\right]$$

$$\left[(1 kg)(2100 \ J/kg°C)(15°C)\right] + \left[1 kg(334{,}000 \ J/kg)\right] + \left[(1 kg)(4186 \ J/kg°C)(15°C)\right]$$

$$31{,}500 J + 334{,}000 J + 62{,}790 J$$

$$428{,}290 J$$

$C_w = 4{,}186 \ J/kg°C$

$C_{ice} = 2100 \ J/kg°C$

$L_f = 334{,}000 \ J/kg$

$m = 1 \ kg$

Home work

How many calories are required to change 400 g of ice at -12°C to steam at 110°C? How many joules?

$$\Delta Q_{ice_{-12°\to 0}} + \Delta Q_{ice \to water} + \Delta Q_{water_{0°\to 100°}} + \Delta Q_{water \to steam} + \Delta Q_{steam_{100°\to 110°}} = \Delta Q_{Total}$$

$$[(0.4)(2090)(12)] + [400(334)] + [0.4(4186)(100)] + [0.4(2256\times 10^3)] + [0.4(2010)(10)]$$

$$10{,}032 + 133{,}600 + 167{,}440 + 902{,}400 + 8{,}040 =$$

$$= 1{,}221{,}512 \text{ J}$$

$$= 1{,}221.5 \text{ kJ}$$

$$\Delta Q = 1.22 \text{ MJ}$$

If 20 g of steam at 100°C is mixed into 80 g of water at 20°C, what will be the final temperature if no thermal energy is lost and no steam escapes?

$$\Delta Q_{s_{g\to l}} + \Delta Q_{s_{100\to T_f}} + \Delta Q_{w_{20\to T_f}} = \emptyset$$

$$[-m L_v] + [m_s c_w (100 - T_f)] + [m_w c_w (T_f - 20)] = \emptyset$$

$$[-(0.02\,\text{kg})(2{,}256{,}000\,\text{J/kg})] + [(0.02)(4186\,\text{J/kg°C})(T_f - 100°\text{C})] + [(0.08\,\text{kg})(4186\,\text{J/kg°C})(T_f - 20°\text{C})] = \emptyset$$

$$-45{,}120\,\text{J} + 83.12 T_f - 8372 + 334.88 T_f - 6697.6 = 0$$

$$418.6 T_f = 60{,}189.6$$

$$T_f = 143.8\,°\text{C}$$

Not all steam is converted!

Real Final Temp: 100°C (w/ leftover steam)

$$\Delta Q_{steam} + \Delta Q_{c_w} = \emptyset$$

$$-m L_v + m_{cw} c_w \Delta T_{cw} = \emptyset$$

$$-m(2{,}256{,}000) + (0.08)(4186)(100 - 20) = \emptyset$$

$$m_s = 0.0119\,\text{kg}$$

11.9 g of steam leftover

Homework

College Physics, Ch. 11

15. What mass of water at 25.0°C must be allowed to come to thermal equilibrium with a 1.85-kg cube of aluminum initially at 1.50×10^2°C to lower the temperature of the aluminum to 65.0°C? Assume any water turned to steam subsequently recondenses.

Al: 1.85 kg

150°C → 65°C

$\Delta T = -85$

$$\Delta Q_{water} + \Delta Q_{al} = \emptyset$$

$$[m(4180)(65° - 25°)] + [1.85(900)(-85)] = \emptyset$$

$$[m(4180)(40)] + [1.85(900)(-85)] = \emptyset$$

$$m\,167{,}200 - 141{,}525 = \emptyset$$

$$m\,167{,}200 = 141525$$

$$\boxed{m = 0.846 \text{ kg}}$$

$m = 846$ g of water

Homework

17. **W** An aluminum cup contains 225 g of water and a 40-g copper stirrer, all at 27°C. A 400-g sample of silver at an initial temperature of 87°C is placed in the water. The stirrer is used to stir the mixture until it reaches its final equilibrium temperature of 32°C. Calculate the mass of the aluminum cup.

$\Delta Q_{al} + \Delta Q_{water} + \Delta Q_{Cu} + \Delta Q_{Ag} = \emptyset$

$T_f = 32°C$
$- 27$
$\Delta T = 5$

87
-32
55

$[m_{al}(900\ J/kg°C)(5)] + [0.225(4186)(5)] + [0.04(387)(5)] + [0.4(234)(-55)] = \emptyset$

$4500\, m_{al} + 4,709.25 + 77.4 - 5148 = \emptyset$

$4,500\, m_{al} - 361.35 = \emptyset$

$4,500\, m_{al} = 361.35$

$m_{al} = 0.0803\ kg$

$= 80.3\ g$ of Aluminum

21. A student drops two metallic objects into a 120-g steel container holding 150 g of water at 25°C. One object is a 200-g cube of copper that is initially at 85°C, and the other is a chunk of aluminum that is initially at 5.0°C. To the surprise of the student, the water reaches a final temperature of 25°C, precisely where it started. What is the mass of the aluminum chunk?

$25-5$

$\Delta Q_{cup} + \Delta Q_{water} + \Delta Q_{Cu} + \Delta Q_{al}$

$[0.120(510)\cancel{(25°-25°)}] + [0.15\cancel{(4186)(25°-25°)}] + [0.2(387)(-60)] + [m_{al}(900)(20)] = \emptyset$

$-4{,}644 + m_{al}\,18{,}000 = \emptyset$

$18{,}000\, m_{al} = 4{,}644$

$m_{al} = 0.258$ kg of Aluminum

$= 258g$

A 10 g piece of ice at -5 Celsius is placed in a 200 g aluminum calorimeter cup with 400 g of water both at 88 Celsius. What is the final equilibrium temperature of the mixture?

Assume all ice melts

$$\Delta Q_{ice_{-5\to 0}} + \Delta Q_{ice\,melt} + \Delta Q_{ice_{0\to T_f}} + \Delta Q_{al_{88\to T_f}} + \Delta Q_{w_{88\to T_f}} = \emptyset$$

$$mc\Delta T + mL_f + mc\Delta T + mc\Delta T + mc\Delta T = \emptyset$$

$$\left[(0.01\,kg)(2{,}100\,J/kg^\circ C)(5^\circ C)\right] + \left[0.01\,kg(334{,}000\,J/kg)\right] + \left[0.01\,kg(4{,}186\,J/kg^\circ C)(T_f - 0^\circ C)\right] + \left[0.2\,kg(900\,J/kg^\circ C)(T_f - 88^\circ C)\right] + \left[0.4\,kg(4186)(T_f - 88)\right] = \emptyset$$

$$105 + 3340 + 41.86T_f + 180T_f - 15{,}840 + 1674.4T_f - 147347.2 = \emptyset$$

$$1896.26\,T_f - 159742.2 = \emptyset$$

$$1896.26\,T_f = 159742.2$$

$$T_f = 84.2^\circ C$$

How much ice at -10 Celsius must be added to 250 g of coffee (assume the specific heat of coffee and water is the same) at 95 Celsius to cool it down to 66 Celsius?

$\Delta T = -29$ Specific heat ice is different

$$\Delta Q_{coffee} + \Delta Q_{ice_{-10^\circ \to 0^\circ}} + \Delta Q_{ice \to water} + \Delta Q_{water_{0^\circ \to 66^\circ}} = \emptyset$$

$$[0.25(4186)(-29)] + [m_i(2090 \cdot 10^\circ)] + [m_i(334 \times 10^3)] + [m_i(4186)(66)] = \emptyset$$

$$631{,}176\, m_i = 30{,}348.5$$

$$m_i = \frac{30{,}348.5}{631{,}176}$$

$$m_i = 0.048\ kg$$

$$= 48 g$$

Area thermal expansion

$$\Delta A = \underbrace{A_0}_{\text{Initial Area}}\underbrace{\gamma}_{\text{Coefficient of Area Expansion}}\underbrace{\Delta T}_{\text{Temp Change}}$$

Linear thermal expansion

pg. 557

$$\Delta L = \underbrace{L_0}_{\text{init length}}\underbrace{\alpha}_{\text{coef of linear expansion}}\underbrace{\Delta T}_{\text{change in temp}}$$

Volumetric expansion

pg. 558

$$\Delta V = \underbrace{V_0}_{\text{initial}}\underbrace{\beta}_{\text{coef of volumetric expansion}}\underbrace{\Delta T}_{\text{Change in Temp}}$$

Table 19.1 Average Expansion Coefficients for Some Materials Near Room Temperature

Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(°C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(°C)^{-1}$
Aluminum	24×10^{-6}	Acetone	1.5×10^{-4}
Brass and bronze	19×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Concrete	12×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Gasoline	9.6×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Turpentine	9.0×10^{-4}
Lead	29×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Steel	11×10^{-6}	Helium[a]	3.665×10^{-3}

$\alpha = 17 \times 10^{-6}$

A copper telephone wire has essentially no sag between poles 35.0 m apart on a cold winter day, -20.0° C. How much longer is the wire on a summer way when the temperature is 35.0° C?

$$\Delta L = L_0 \alpha \Delta T$$

$$= (35.0\,m)(17 \times 10^{-6})(55\,°C)$$

$$\Delta L = 0.0327\,m$$

$$= 3.27\,cm$$

$$= 32.7\,mm$$

$\beta = 87 \times 10^{-6}\ 1/C°$

A sample of lead has a mass of 20.0 kg and a density of 11.3×10^3 kg/m^3 at 0°C. (a) What is the density of the lead at 90.0° C? (b) What is the mass of the sample of lead at 90.0°C?

$$V_0 = \frac{20\ \cancel{kg}}{11.3 \times 10^3\ \cancel{kg}/m^3} = 0.00177\ m^3$$

a) $\Delta V = V_0 \beta \Delta T$

$\Delta V = (0.00177\ m^3)(87 \times 10^{-6}\ \cancel{1/C°})(90\ \cancel{C°})$

$\Delta V = 0.0000138\ m^3$

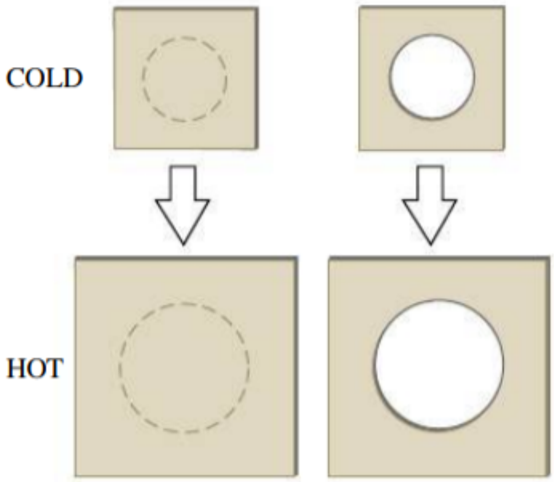
$V_f = \Delta V + V_0$

$V_f = 0.001287\ m^3$

$$\frac{20\ kg}{0.001287\ m^3} = 11.211 \times 10^3\ kg/m^3$$

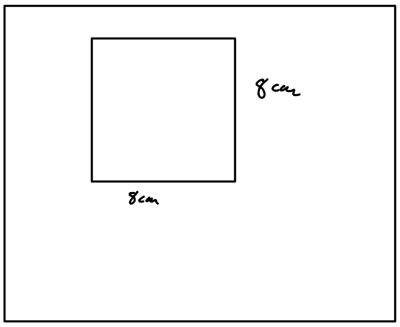
b) 20 kg

$A = \pi r^2 =$



Do this & checks

A square hole 8.00 cm on each side is cut in a sheet of copper. (a) Calculate the change in the area of this hole resulting when the temperature of the sheet is increased by 50.0 K. (b) Does this change represent a decrease or an increase in the area of the whole?



Homework

The active element of a certain laser is made of a glass rod 30.0 cm long and 1.50 cm in diameter. Assume the average coefficient of linear expansion of the glass is equal to 9.00 x 10^{-6} /°C. If the temperature of the rod increases by 65.0° C, what is the increase in length, diameter, and volume?

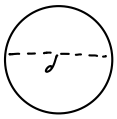
Length:

$\Delta L = L_0 \alpha \Delta T$

$\Delta L = 30\text{cm}\,(9 \times 10^{-6}\ {}^\circ C^{-1})(65^\circ C)$

$\Delta L = 0.017\text{cm}$

Diameter:



$\Delta L = L_0 \alpha \Delta T$

$= 1.5\text{cm}\,(9 \times 10^{-6}\ {}^\circ C^{-1})(65^\circ C)$

$\Delta L = 0.000878$

$\Delta L = 8.78 \times 10^{-4}\text{cm}$

Volume

$\Delta V = V_0 \beta \Delta T \qquad \beta = 3\alpha$

$\beta = 3(9 \times 10^{-6})$

$\beta = 2.7 \times 10^{-5}$

$V_0 = \frac{\pi}{4}(1.5)^2(30)$

$V_0 = 53\text{cm}^3$

$\Delta V = 53\text{cm}^3(2.7 \times 10^{-5})(65^\circ C)$

$\Delta V = 0.093\text{cm}^3$

13. A certain steel railroad rail is 13 yd in length and weighs 70.0 lb/yd. How much thermal energy is required to increase the length of such a rail by 3.0 mm? *Note:* Assume the steel has the same specific heat as iron.

$\Delta L = L_0 \alpha \Delta T$

1 – Temp change to change length diff
2 – Energy required to change temp by diff

$L_0 = 13 yd = 11{,}890 mm$

$3 = 11{,}890 (12 \times 10^{-6}) \Delta T$

$\Delta T = 21°C$

$\frac{70 lbs}{1 yd} \cdot 13 yd = 910 lbs = 414 kg$

$m = 414 kg$

$\Delta Q = m c \Delta T$

$c = 470 J/kg°C$

$\Delta Q = 414 kg (470 J/kg°C)(21°C)$

$\Delta Q = 4{,}086{,}180 J$

$\Delta Q = 4.09 MJ = 4.09 \times 10^6 J$

Check tomorrow

The concrete sections of a certain superhighway are designed to have a length of 25.0 m. The sections are poured and cured at 10.0° C. What minimum spacing should the engineer leave between the sections to eliminate buckling is the concrete is to reach a temperature of 50.0°C?

$\Delta L = L_0 \alpha \Delta T$

$\alpha = 12 \times 10^{-6}\ °C^{-1}$ ← (from notes)

$\Delta T = 40°C$

$L_0 = 25m$

$\Delta L = 25m\,(12 \times 10^{-6}\ \cancel{°C^{-1}})(40\cancel{°C})$

$\Delta L = 0.012\ m$

$= 1.2cm$

$\alpha = 10 \times 10^{-6}\ °C^{-1}$

$\Delta T = 40°C$

$L_0 = 25m$

$\Delta L = 25m\,(10 \times 10^{-6}\ \cancel{°C^{-1}})(40\cancel{°C})$

Doesn't match teacher notes

$\Delta L = 0.01\ m$

$\Delta L = 1cm$

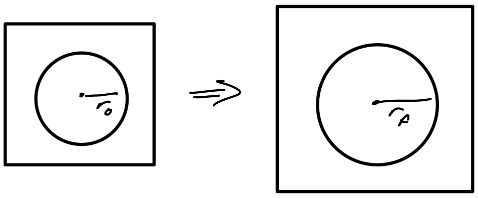
10×10^{-6}

0.00001

$$\begin{array}{r} 0.00001 \\ \times\ 40 \\ \hline 0.0004 \end{array} \qquad \begin{array}{r} 0.0004 \\ \times\ 25 \\ \hline 20 \\ +\ 80 \\ \hline 0.0100 \end{array}$$

0.01m

A pair of eyeglass frames is made of epoxy plastic. At room temperature (20.0° C), the frames have circular lens wholes 2.20 cm in radius. To what temperature must the frames be heated is lenses 2.21 cm in radiu are to be inserted in them? The average linear coefficient of expansion for epoxy is 1.30 x 10^{-4} /°C.



$r_o = 2.20cm$ $\quad$ $r_f = 2.21cm$

$\Delta L = 0.02\ cm$ $\quad$ $L_o = 2r$

$\Delta L = L_o \alpha \Delta T$

$0.02 = 4.4\,(1.3\times10^{-4}\,°C^{-1})(T_f - 20°)$

$T_f = 55°C$

5. QIC A 3.00-g copper coin at 25.0°C drops 50.0 m to the ground. (a) Assuming 60.0% of the change in gravitational potential energy of the coin–Earth system goes into increasing the internal energy of the coin, determine the coin's final temperature. (b) Does the result depend on the mass of the coin? Explain.

?

$c = 390$

$U = mgh$

mass (gravity)(height)

$-\Delta U = \Delta Q$

$-(mgh_f - mgh_i) = mc\Delta T$

$-\cancel{m}g(h_f - h_i) = \cancel{m}c\,\Delta T$

$\Delta T = \frac{-g}{c}(h_f - h_i)$

$= \frac{-9.8}{390}(-50m)$

60% got dropped on slides

for 100%: $\Delta T = 1.25°C$

$60\% = 1.25(0.6)$

$= 0.75°C$

$T_f = 25.75°C$

$T_f = T_i + \Delta T$

$T_f = 25° + 1.25°$

$T_f = 26.3°C$

26. GP The density of gasoline is 7.30×10^2 kg/m^3 at 0°C. Its average coefficient of volume expansion is $9.60 \times 10^{-4}(°C)^{-1}$, and note that 1.00 gal = 0.003 80 m^3. (a) Calculate the mass of 10.0 gal of gas at 0°C. (b) If 1.000 m^3 of gasoline at 0°C is warmed by 20.0°C, calculate its new volume. (c) Using the answer to part (b), calculate the density of gasoline at 20.0°C. (d) Calculate the mass of 10.0 gal of gas at 20.0°C. (e) How many extra kilograms of gasoline would you get if you bought 10.0 gal of gasoline at 0°C rather than at 20.0°C from a pump that is not temperature compensated?

a) $10.0 \text{ gal} = 0.0379 \text{ m}^3$

$\frac{7.3\times10^2 \text{ kg}}{1 \text{ m}^3}(0.0379 \text{ m}^3) = 27.67 \text{ kg}$

$= 27.7 \text{ kg}$

b) $m = 730 \text{ kg}$

$\Delta V = V_0 \beta \Delta T$

$\Delta V = 1 \text{ m}^3 (9.6\times10^{-4} °C^{-1})(20°C)$

$\Delta V = 0.0192 \text{ m}^3$

$V_f = V_i + \Delta V$

$V_f = 1.02 \text{ m}^3$

c) @0°C $\frac{730 \text{ kg}}{1 \text{ m}^3}$

@20°C $\frac{730 \text{ kg}}{1.02 \text{ m}^2}$

density = 715.7 kg/m^3

d) @ 20°C density = 715.7 kg/m^3

$10 \text{ gal} = 0.0379 \text{ m}^3$

$\frac{715.7 \text{ kg}}{1 \text{ m}^3} = \frac{27.1 \text{ kg}}{0.0379 \text{ m}^3}$

e) 0.6 kg more of gas in 10 gal @ 0°C than 10 gal @ 20°C

$$P = \frac{F}{A}$$

$R = 0.082057$ L atm / mol K

$$PV = nRT$$

$R = 8.314$ J/mol·K

$$PV = Nk_BT$$

$k_B = 1.38 \times 10^{-23}$ J/K

$N_A = 6.022 \times 10^{23}$ particles/mole

A rigid tank contains 1.50 moles of an ideal gas. Determine the number of moles of gas that must be withdrawn from the tank to lower the pressure of the gas from 25.0 atm to 5.00 atm. Assume the volume of the tank and the temperature of the gas remain constant.

$PV = nRT$

$n_i = 1.50$ moles $\quad n_f = ?$

$P_i = 25.0$ atm $\quad P_f = 5.00$ atm

$$\frac{n_i}{P_i} = \frac{RT}{V} = \frac{n_f}{P_f}$$

$$\frac{1.5\text{ mol}}{25\text{ atm}} = \frac{0.3\text{ mol}}{5\text{ atm}}$$

$n_f = 0.3$ mol

$$\begin{array}{r} 1.5 \\ -0.3 \\ \hline \end{array}$$

$\Delta n = 1.2$ mol

Check

Homework

A gas is confined in a tank at a pressure of 11.0 atm and a temperature of 25.0°C. If 2/3 of the gas is withdrawn and the temperature is raised to 75.0°C, what is the pressure of the gas remaining in the tank?

$P_i = 11.0$ atm $\quad P_f = ?$

$T_i = 25°C \quad T_f = 75.0°C$

$V_f = V_i$

$R_f = R_i$

$n_f = \frac{2}{3} n_i$

$PV = nRT$

$P = \frac{nRT}{V}$

$\frac{P}{T} = \frac{nR}{V}$

$\frac{P_i}{T_i n_i} = \frac{P_f}{T_f n_f}$

$\frac{11 \text{ atm}}{(298 K)\, n_i} = \frac{P_f}{(368 K)\, \frac{1}{3} n_i}$

$0.0369 = \frac{P_f}{}$

$P_f = 4.28$ atm

work & checks

Gas is contained in an 8.00 L vessel at a temperature of 20.0°C and a pressure at 9.00 atm. (a) Determine the number of moles of gas in the vessel. (b) How many molecules are in the vessel?

$V = 8.0\ L$

$T = 20.0\ °C = 293\ K$

$P = 9.00\ atm$

$R = 0.082057$

a) $PV = nRT$

$$n = \frac{PV}{RT} = \frac{9(8)}{(0.082057)(293\ K)}$$

$n = 2.99\ mol$

b) $2.99 \times (6.022 \times 10^{23})$

$= 1.8 \times 10^{24}$ molecules

An auditorium has dimensions 10.0 m x 20.0 m x 30.0 m. How many molecules of air fill the auditorium at 20.0°C and a pressure of 101 kPa?

$$PV = N k_b T$$

$$N = \frac{PV}{k_b T}$$

$$N = \frac{(101 \times 10^3 \text{ Pa})(10 \cdot 20 \cdot 30)}{(1.38 \times 10^{-23})(293)}$$

$$N = 1.5 \times 10^{29} \text{ molecules}$$

In a state of the art vacuum system, pressures as low as 1.00×10^{-9} Pa are attained. Calculate the number of molecules in a $1.00\ m^3$ vessel at this pressure and a temperature of 27.0°C.

$PV = N k_b T$

$T = 273 + 27$

$$N = \frac{PV}{k_b T} = \frac{(1 \times 10^{-9})(1)}{(1.38 \times 10^{-23})(300°K)}$$

$N = 2.4 \times 10^{11}$ particles

29. One mole of oxygen gas is at a pressure of 6.00 atm and a temperature of 27.0°C. (a) If the gas is heated at constant volume until the pressure triples, what is the final temperature? (b) If the gas is heated so that both the pressure and volume are doubled, what is the final temperature?

$P_i = 6$ atm

$P_f = 3P_i = 18$ atm

$T_i = 27°C = 300°K$

$V_f = V_i$

$n_f = n_i$

$R_f = n_i$

a)

$$\frac{P_i}{T_i} = \frac{P_f}{T_f}$$

$$\frac{300}{6} = \frac{T_f}{18}$$

$T_f = 900°K$

$P_i = 6$ atm $\quad P_f = 2P_i = 12$ atm

$V_i = ?$ $\quad V_f = 2V_i$

$T_i = 300K$ $\quad T_f = ?$

$$\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$$

$$= \frac{6 \cancel{V_i}}{300} = \frac{12 \cdot 2 \cancel{V_i}}{T_f}$$

$T_f = 1200K$

Homework

College Physics, Ch. 10

33. Gas is confined in a tank at a pressure of 11.0 atm and a temperature of 25.0°C. If two-thirds of the gas is withdrawn and the temperature is raised to 75.0°C, what is the new pressure of the gas remaining in the tank?

$$\frac{P}{nT} = \frac{R}{V} = \frac{P_f}{n_f T_f}$$

$$\begin{array}{r} 277 \\ +\ 75 \\ \hline \end{array}$$

$$\frac{11\,\text{atm}}{\cancel{n_i}\,(298°K)} = \frac{P_f}{\tfrac{1}{3}\cancel{n_i}\,(348°K)}$$

$$P_f = \frac{11\,(348)}{3\,(298)}$$

$$P_f = 4.28\ \text{atm}$$

Homework

34. Gas is contained in an 8.00-L vessel at a temperature of 20.0°C and a pressure of 9.00 atm. (a) Determine the number of moles of gas in the vessel. (b) How many molecules are in the vessel?

a) $PV = nRT$

$$\begin{array}{r} 273 \\ +\ 20 \\ \hline 293 \end{array}$$

$$n = \frac{PV}{RT}$$

$$= \frac{9\,atm\,(8\,L)}{(0.082057)(293\,°K)}$$

$$= 0.04\ mol$$

36. The density of helium gas at 0°C is $\rho_0 = 0.179\ \text{kg/m}^3$. The temperature is then raised to $T = 100°\text{C}$, but the pressure is kept constant. Assuming the helium is an ideal gas, calculate the new density ρ_f of the gas.

$P_i = P_f$

$T_i = 0°C = 273°K \qquad T_f = 100°C = 373°K$

$\rho_0 = 0.179 \qquad \rho_f = ?$

$n_i = n_f \quad \therefore m_i = m_f$

$V = \rho/m$

$PV = nRT$

$\frac{V}{T} = \frac{nR}{P}$

$\frac{V_i}{T_i} = \frac{V_f}{T_f}$

$\frac{m}{T_i \rho_i} = \frac{m}{T_f \rho_f}$

$\frac{1}{T_i \rho_i} = \frac{1}{T_f \rho_f}$

$\rho_f = \frac{T_i \rho_i}{T_f}$

$= \frac{273(0.179)}{373}$

$\rho_f = 0.16\ \text{kg/m}^3$

Works & Check

College Physics, Ch. 10

40. A sealed cubical container 20.0 cm on a side contains three times Avogadro's number of molecules at a temperature of 20.0°C. Find the force exerted by the gas on one of the walls of the container.