

***Basic Principles and Calculations in Chemical
Engineering 9th edition Himmelblau Solutions
Manual***

SKU: 9780137327232-SOLUTIONS

Chapter 2 Solutions

2.1 Units of Measure

2.1.1

- | | |
|-----|------------------------|
| (a) | N/mm or nm (nanometer) |
| (b) | °C/M/s |
| (c) | 100 kPa |
| (d) | 273.15 K |
| (e) | 1.50m, 45 kg |
| (f) | 250°C |
| (g) | J/s |
| (h) | 250 N |

- 2.1.2 a. The device measures equivalent masses when it is balanced (both pans aligned horizontally).
 b. The compressed spring measures the force under the influence of gravity. If this system were applied on the surface of the moon, the measurement would be much smaller.

2.2 Unit Conversions

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2.2.1

- (a) $\frac{2.5 \cancel{\text{mi}}}{\cancel{\text{mi}}} \left| \frac{1610 \text{ m}}{\cancel{\text{mi}}} \right| = 4.0 \times 10^3 \text{ m or } 4.0 \text{ km}$
- (b) $\frac{52.66 \cancel{\text{Btu}}}{\cancel{\text{Btu}}} \left| \frac{1.055 \text{ kJ}}{\cancel{\text{Btu}}} \right| = 55.56 \text{ kJ}$
- (c) $\frac{5.00 \cancel{\text{hp}}}{\cancel{\text{hp}}} \left| \frac{0.7457 \text{ kW}}{\cancel{\text{hp}}} \right| = 3.73 \text{ kW}$
- (d) $\frac{50. \cancel{\text{gal}}}{\cancel{\text{min}}} \left| \frac{3.875 \times 10^{-3} \text{ m}^3}{\cancel{\text{gal}}} \right| \left| \frac{\cancel{\text{min}}}{60 \text{ s}} \right| = 3.2 \times 10^{-3} \text{ m}^3 \text{ s}^{-1}$
- (e) $\frac{22.5 \cancel{\text{lb}_f}}{\cancel{\text{in}^2}} \left| \frac{6.958 \text{ kPa}}{\cancel{\text{lb}_f/\text{in}^2}} \right| = 157 \text{ kPa}$
- (f) $\frac{45.6 \cancel{\text{s}} \cancel{\text{lug}}}{\cancel{\text{s}}} \left| \frac{32.174 \cancel{\text{lb}_m}}{\cancel{\text{s}} \cancel{\text{lug}}} \right| \left| \frac{0.4536 \text{ kg}}{\cancel{\text{lb}_m}} \right| = 665 \text{ kg s}^{-1}$
- (g) $\frac{17.0 \cancel{\text{hp}} \cancel{\text{h}}}{\cancel{\text{hp}} \cancel{\text{s}}} \left| \frac{745.7 \text{ J}}{\cancel{\text{hp}} \cancel{\text{s}}} \right| \left| \frac{3600 \cancel{\text{s}}}{\cancel{\text{h}}} \right| = 4.56 \times 10^6 \text{ J} = 4.56 \times 10^3 \text{ kJ} = 4.56 \text{ MJ}$
- (h) $\frac{35.9 \cancel{\text{gal}}}{\cancel{\text{s}} \cancel{\text{ft}^2}} \left| \frac{3.875 \times 10^{-3} \text{ m}^3}{\cancel{\text{gal}}} \right| \left| \frac{\cancel{\text{ft}^2}}{0.3048^2 \text{ m}^2} \right| = 1.50 \text{ m}^3 \text{ m}^{-2} \text{ s}^{-1}$
- (i) $357^\circ \text{F} + 459.67 = 816.67^\circ \text{R} \quad \frac{816.67^\circ \text{R}}{9^\circ \text{R}} \left| \frac{5 \text{ K}}{9^\circ \text{R}} \right| = 454 \text{ K}$

$$(j) \frac{7.6 \text{ lb}_m}{\text{ft}^3} \left| \frac{0.4536 \text{ kg}}{\text{lb}_m} \right| \frac{\text{ft}^3}{0.02832 \text{ m}^3} = 120 \text{ kg m}^{-3}$$

2.2.2

$$(a) \frac{6.000 \text{ ft}}{1} \left| \frac{0.3048 \text{ m}}{\text{ft}} \right| \frac{10^6 \mu\text{m}}{\text{m}} = 1.829 \times 10^6 \mu\text{m}$$

$$(b) \frac{100 \text{ km}}{\text{h}} \left| \frac{3.937 \times 10^4 \text{ in}}{\text{km}} \right| \frac{\text{h}}{3600 \text{ s}} \left| \frac{\text{s}}{10^6 \mu\text{s}} \right| = 1.094 \times 10^{-3} \text{ in } \mu\text{s}^{-1}$$

$$(c) \frac{500 \text{ K}}{1} \left| \frac{9^\circ \text{R}}{5 \text{ K}} \right| = 900^\circ \text{R} \quad 900^\circ \text{R} - 459.67 = 440^\circ \text{F}$$

$$(d) \frac{1 \times 10^6 \text{ Btu}}{\text{h}} \left| \frac{2.93 \times 10^{-4} \text{ kW h}}{\text{Btu}} \right| = 293 \text{ kW}$$

$$(e) \frac{7.5 \text{ kg}}{\text{m}^{-3}} \left| \frac{\text{m}^{-3}}{28.3776 \text{ bushel}} \right| \frac{2.2046 \text{ lb}_m}{\text{kg}} \left| \frac{16 \text{ oz}}{\text{lb}_m} \right| = 9.3 \text{ oz bushel}^{-1}$$

$$(f) \frac{15.367 \text{ lb}_m \text{ ft}^2}{\text{s}^2} \left| \frac{\text{lb}_f \text{ s}^2}{32.174 \text{ lb}_m \text{ ft}} \right| \frac{1.285 \times 10^{-3} \text{ Btu}}{\text{lb}_f \text{ ft}} = 6.1374 \times 10^{-4} \text{ Btu}$$

$$(g) \frac{0.2433 \text{ kg}}{\text{m s}^2} \left| \frac{\text{N s}^2}{\text{kg m}} \right| \frac{\text{Pa m}^2}{\text{N}} \left| \frac{1.414 \times 10^{-4} \text{ psi}}{\text{Pa}} \right| = 3.440 \times 10^{-5} \text{ psi}$$

$$(h) \frac{10.1 \text{ A h}}{1} \left| \frac{\text{Wh}}{\text{A h}} \right| \frac{\text{kW}}{1000 \text{ W}} = 0.0101 \text{ kW}$$

$$(i) \frac{32.17 \text{ ft}}{\text{s}^2} \left| \frac{3600^2 \text{ s}^2}{\text{h}^2} \right| \frac{0.3048 \text{ m}}{\text{ft}} \left| \frac{1000 \text{ mm}}{\text{m}} \right| = 1.271 \times 10^{11} \text{ mm h}^{-2}$$

$$(j) \frac{0.779 \text{ lb}_m \text{ ft}}{\text{s}^2} \left| \frac{\text{lb}_f \text{ s}^2}{32.174 \text{ lb}_m \text{ ft}} \right| \frac{3.766 \times 10^{-7} \text{ kW h}}{\text{lb}_f \text{ ft}} \left| \frac{3600 \text{ s}}{\text{h}} \right| = 3.28 \times 10^{-5} \text{ kW}$$

2.2.3 Fractional reduction in miles driven = 1000/13500 = 0.07407

Gasoline saved = 0.07407(136.8) = 10.13 billion gallons

2.2.4

$$\frac{2000 \text{ Btu}}{\text{h}} \left| \frac{\text{kWh}}{11.2 \text{ Btu}} \right| \frac{\$0.14}{\text{kWh}} \left| \frac{24 \text{ h}}{\text{d}} \right| \frac{30 \text{ d}}{\text{mo}} = \$18,000 \text{ mo}^{-1}$$

2.2.5

$$\frac{4.24 \text{ ly}}{1} \left| \frac{2.99792 \times 10^8 \text{ m}}{\text{s}} \right| \frac{3600 \text{ s}}{\text{h}} \left| \frac{24 \text{ h}}{\text{d}} \right| \frac{365 \text{ d}}{\text{y}} \left| \frac{\text{mi}}{1610 \text{ m}} \right| \frac{\text{AU}}{9.29 \times 10^7 \text{ mi}} = 2.68 \times 10^6 \text{ AU}$$

2.2.6

$$\frac{8.6 \text{ ly}}{1} \left| \frac{2.99792 \times 10^8 \text{ m}}{\text{s}} \right| \frac{3600 \text{ s}}{\text{h}} \left| \frac{24 \text{ h}}{\text{d}} \right| \frac{365 \text{ d}}{\text{y}} \left| \frac{\text{pc}}{3.0867 \times 10^{16} \text{ m}} \right| = 2.6 \text{ pc}$$

2.2.7

$$\frac{400,000 \text{ bbl}}{\cancel{\text{d}}} \left| \frac{42 \text{ gal}}{\text{bbl}} \right| \left| \frac{3.875 \cancel{\text{L}}}{\text{gal}} \right| \left| \frac{850 \cancel{\text{g}}}{\cancel{\text{L}}} \right| \left| \frac{\text{lb}_m}{454.3 \cancel{\text{g}}} \right| \left| \frac{\cancel{\text{d}}}{24 \text{ h}} \right| = 5.075 \times 10^6 \text{ lb}_m \text{ h}^{-1}$$

2.2.8

$$\frac{18 \times 15 \times 8 \cancel{\text{in}^3}}{297 \cancel{\text{s}}} \left| \frac{2.54^3 \cancel{\text{cm}^3}}{\cancel{\text{in}^3}} \right| \left| \frac{\cancel{\text{L}}}{1000 \cancel{\text{cm}^3}} \right| \left| \frac{\text{gal}}{3.875 \cancel{\text{L}}} \right| \left| \frac{60 \cancel{\text{s}}}{\text{min}} \right| = 1.8 \text{ gal min}^{-1}$$

2.2.9

$$\frac{12 \cancel{\text{km}}}{\text{L}} \left| \frac{3.875 \text{ L}}{\text{gal}} \right| \left| \frac{\text{mi}}{1.61 \cancel{\text{km}}} \right| = 28.9 \text{ mi/gal}$$

2.2.10

$$\frac{\$1.29 \text{ CAD}}{\text{L}} \left| \frac{\$0.79 \text{ USD}}{\$1 \text{ CAD}} \right| \left| \frac{3.875 \text{ L}}{\text{gal}} \right| = \$3.95 \text{ USD/gal}$$

2.2.11

$$\frac{8.314 \text{ kPa m}^3}{\text{kgmol K}} \left| \frac{\text{atm}}{101.3 \text{ kPa}} \right| \left| \frac{35.31 \cancel{\text{ft}^3}}{\cancel{\text{m}^3}} \right| \left| \frac{\text{kgmol}}{2.2046 \text{ lbmol}} \right| \left| \frac{5 \text{ K}}{9^\circ \text{ R}} \right| = 0.7303 \frac{\text{atm ft}^3}{\text{lbmol}^\circ \text{ R}}$$

2.2.12

$$V = Ah = \frac{3500 \cancel{\text{ft}^2}}{\cancel{\text{ft}}} \left| \frac{3 \cancel{\text{in}}}{12 \cancel{\text{in}}} \right| \left| \frac{\text{ft}}{\cancel{\text{ft}}} \right| \left| \frac{7.481 \text{ gal}}{\cancel{\text{ft}^3}} \right| = 6546 \text{ gal}$$

2.2.13

a.

Basis: 1 mi³

$$\frac{1 \text{ mi}^3}{\cancel{\text{mi}^3}} \left| \left(\frac{5280 \cancel{\text{ft}}}{1 \cancel{\text{mi}}} \right)^3 \right| \left| \left(\frac{12 \cancel{\text{in}}}{1 \cancel{\text{ft}}} \right)^3 \right| \left| \left(\frac{2.54 \cancel{\text{cm}}}{1 \cancel{\text{in}}} \right)^3 \right| \left| \left(\frac{1 \cancel{\text{m}}}{100 \cancel{\text{cm}}} \right)^3 \right| = \boxed{4.17 \times 10^9 \text{ m}^3}$$

b.

Basis: 1 ft³/s

$$\frac{1 \cancel{\text{ft}^3}}{1 \cancel{\text{s}}} \left| \frac{60 \cancel{\text{s}}}{1 \cancel{\text{min}}} \right| \left| \frac{7.48 \text{ gal}}{1 \cancel{\text{ft}^3}} \right| = \boxed{449 \text{ gal/min}}$$

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2.2.14

$$\text{a. } \frac{0.04 \text{ g}}{(\text{min})(\text{m}^3)} \left| \frac{60 \text{ min}}{1 \text{ hr}} \right| \left| \frac{(12 \text{ in})^3}{1 \text{ ft}^3} \right| \left| \frac{1 \text{ lb}_m}{454 \text{ g}} \right| = \boxed{9.14 \frac{\text{lb}_m}{(\text{hr})(\text{ft}^3)}}$$

$$\text{b. } \frac{2 \text{ L}}{\text{s}} \left| \frac{3600 \text{ s}}{1 \text{ hr}} \right| \left| \frac{24 \text{ hr}}{1 \text{ day}} \right| \left| \frac{1 \text{ ft}^3}{28.32 \text{ L}} \right| = \boxed{6.1 \times 10^3 \frac{\text{ft}^3}{\text{day}}}$$

$$\text{c. } \frac{6 (\text{in.})(\text{cm}^2)}{(\text{yr})(\text{s})(\text{lb}_m)(\text{ft}^2)} \left| \frac{1 \text{ ft}^2}{(12 \text{ in})^2} \right| \left| \frac{(1 \text{ in})^2}{(2.54 \text{ cm})^2} \right| \left| \frac{1 \text{ yr}}{365 \text{ days}} \right| \left| \frac{1 \text{ day}}{24 \text{ hr}} \right| \left| \frac{1 \text{ hr}}{3600 \text{ s}} \right| \left| \frac{2.2 \text{ lb}_m}{1 \text{ kg}} \right|$$

$$\frac{1 \text{ ft}}{12 \text{ in}} \left| \frac{0.3048 \text{ m}}{1 \text{ ft}} \right| = \boxed{1.14 \times 10^{-11} \frac{\text{m}}{(\text{kg})(\text{s}^2)}}$$

2.2.15

a. Basis: 60.0 mile/hr

$$\frac{60.0 \text{ mile}}{\text{hr}} \left| \frac{5280 \text{ ft}}{1 \text{ mile}} \right| \left| \frac{1 \text{ hr}}{3600 \text{ sec}} \right| = \boxed{88 \frac{\text{ft}}{\text{sec}}}$$

b. Basis: 50.0 lb_m/(in)²

$$\frac{50.0/\text{lb}_m}{(\text{in})^2} \left| \frac{454 \text{ g}}{1 \text{ lb}} \right| \left| \frac{1 \text{ kg}}{1000 \text{ g}} \right| \left| \frac{1 (\text{in})^2}{(2.54 \text{ cm})^2} \right| \left| \frac{(100 \text{ cm})^2}{(1 \text{ m})^2} \right| = \boxed{3.52 \times 10^4 \frac{\text{kg}}{\text{m}^2}}$$

c. Basis: 6.20 cm/(hr)²

$$\frac{6.20 \text{ cm}}{(\text{hr})^2} \left| \frac{1 \text{ m}}{100 \text{ cm}} \right| \left| \frac{10^9 \text{ nm}}{1 \text{ m}} \right| \left| \frac{1 (\text{hr})^2}{(3600 \text{ sec})^2} \right| = \boxed{4.79 \frac{\text{nm}}{\text{sec}^2}}$$

2.2.16

$$\frac{20 \text{ hp}}{1 \text{ hp}} \left| \frac{0.7457 \text{ kW}}{1 \text{ hp}} \right| = 14.91 \text{ kW}$$

No, not enough power even at 100% efficiency; 68 kW = 91.2 hp.

2.2.17

$$\frac{1 \text{ hr}}{525 \text{ mile}} \left| \frac{2200 \text{ gal}}{1 \text{ hr}} \right| \frac{1000 \text{ mile}}{\text{ }} = \boxed{4190.5 \text{ gal}}$$

$$\frac{1 \text{ hr}}{475 \text{ mile}} \left| \frac{2000 \text{ gal}}{1 \text{ hr}} \right| \frac{1000 \text{ mile}}{\text{ }} = \boxed{\frac{4210 \text{ gal}}{(20 \text{ gal})}}$$

None: 20 gal more are needed.

2.2.18

Let t_A be the time for A to paint one house; t_B for B
A does a house in 5 hours, or 1 house/5 hr. B does one house
in 3 hours, or 1 house/3 hr.

$$\frac{1 \text{ house}}{5 \text{ hr}} \left| \frac{t_A \text{ hr}}{\text{ }} \right| + \frac{1 \text{ house}}{3 \text{ hr}} \left| \frac{t_B \text{ hr}}{\text{ }} \right| = 1 \text{ house}$$

$$\text{Also } t_A = t_B \text{ so that } \frac{3}{15} t_A + \frac{5}{15} t_A = 1 \text{ or } \frac{8}{15} t_A = 1$$

$$t_A = \frac{15}{8} \text{ hr} = t_B = 1.875 \text{ hr or } \boxed{112.5 \text{ min}}$$

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2.2.19

$$\frac{20.0 \text{ g}}{(\text{m})(\text{s})} \left| \frac{1 \text{ lb}_m}{453.6 \text{ g}} \right| \left| \frac{0.3048 \text{ m}}{1 \text{ ft}} \right| \left| \frac{3600 \text{ s}}{1 \text{ hr}} \right| \left| \frac{1 (\text{lb}_f)(\text{s}^2)}{32.174 (\text{lb}_m)(\text{ft})} \right| \left| \frac{1 (\text{hr})^2}{(3600)^2 \text{ s}^2} \right|$$

$$= \boxed{1.16 \times 10^{-7} \frac{(\text{lb}_f)(\text{hr})}{\text{ft}^2}}$$

2.2.20

$$\frac{1.0 \text{ Btu}}{(\text{hr})(\text{ft}^2)} \left(\frac{^\circ \text{F}}{\text{ft}} \right) \left| \frac{24 \text{ hrs}}{1 \text{ day}} \right| \left| \frac{1 \text{ ft}^2}{(12 \text{ in})^2} \right| \left| \frac{1 \text{ in}^2}{(2.54 \text{ cm}^2)} \right| \left| \frac{(100 \text{ cm})^2}{1 \text{ m}^2} \right| \left| \frac{1.8^\circ \text{F}}{1^\circ \text{C}} \right| \left| \frac{2.54 \text{ cm}}{\text{in}} \right|$$

$$\frac{252 \text{ cal}}{1 \text{ Btu}} \left| \frac{12 \text{ in}}{1 \text{ ft}} \right| \left| \frac{4.184 \text{ J}}{1 \text{ cal}} \right| \left| \frac{1 \text{ kJ}}{1000 \text{ J}} \right| = 1.49 \times 10^4 \frac{\text{kJ}}{(\text{day})(\text{m}^2)(^\circ \text{C}/\text{cm})}$$

2.2.21 Basis: 1 lb H₂O

$$\text{a.} \quad KE = \frac{1}{2}mv^2 = \frac{1}{2} \left| \frac{1 \text{ lb}_m}{1} \right| \left| \left(\frac{3 \text{ ft}}{\text{s}} \right)^2 \right| \left| \frac{(\text{s}^2)(\text{lb}_f)}{32.174(\text{ft})(\text{lb}_m)} \right| = 0.14(\text{ft})(\text{lb}_f)$$

b. Let A = area of the pipe and v = water velocity. The flow rate is

$$q = Av = \left(\frac{\pi D^2}{4} \right) (v)$$

$$\frac{\pi}{4} \left| \frac{(2 \text{ in})^2}{1} \right| \left| \frac{(1 \text{ ft})^2}{(12 \text{ in})^2} \right| \left| \frac{3 \text{ ft}}{\text{s}} \right| \left| \frac{60 \text{ s}}{1 \text{ min}} \right| \left| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \right| = \boxed{29.37 \text{ gal/min}}$$

2.2.22

$$PE = \frac{75 \text{ gal}}{\text{min}} \left| \frac{8.33 \text{ lb}_m}{\text{gal}} \right| \left| \frac{32.2 \text{ ft}}{\text{sec}^2} \right| \left| \frac{100}{\text{ft}} \right| \left| \frac{60 \text{ s}}{\text{hr}} \right| \left| \frac{\text{s}^2 \cdot \text{lb}_f}{32.2 \text{ lb}_m \cdot \text{ft}} \right| \left| \frac{\text{Btu}}{778 \text{ ft} \cdot \text{lb}_f} \right| = 4818 \text{ Btu/hr}$$

$$\text{Pump Work} = \frac{2 \text{ hp}}{1} \left| \frac{2545 \text{ Btu}}{\text{hp} \cdot \text{hr}} \right| = 5090 \text{ Btu/hr}$$

$$\text{Rate of energy input for heating} = PW - PE = 5090 - 4818 = 272 \text{ Btu/hr}$$

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2.2.23 The object has a mass of 21.3 kg (within a precision of $\pm .1$ kg). The weight is the force used to support the mass.

2.2.24 In American Engineering System

$$\text{Power} = FV$$

$$= \frac{800 \text{ lb}_f}{1} \left| \frac{300 \text{ ft}}{\text{min}} \right| = \boxed{2.4 \times 10^5 \frac{(\text{lb}_f)(\text{ft})}{\text{min}}} \text{ or } 7.27 \text{ hp}$$

In SI

$$\text{Power} = \frac{4000 \text{ N}}{1} \left| \frac{1.5 \text{ m}}{\text{s}} \right| \left| \frac{1 (\text{watt})(\text{s})}{1(\text{N})(\text{m})} \right|$$

$$= \boxed{6000 \text{ watts}}$$

2.2.25

$$\begin{aligned}
 \text{KE} &= \frac{1}{2} m v^2 \\
 &= \frac{1}{2} \left| \frac{2300 \text{ kg}}{0.454 \text{ kg}} \right| \left| \frac{1 \text{ lb}_m}{\text{kg}} \right| \left(\frac{10.0 \text{ ft}}{\text{s}} \right)^2 \left| \frac{1}{32.2 \frac{\text{lb}_m}{\text{ft}} \frac{\text{ft}}{\text{sec}^2}} \right| \left| \frac{1 \text{ Btu}}{778.2(\text{ft})(\text{lb}_f)} \right| \\
 &= \boxed{10.11 \text{ Btu}}
 \end{aligned}$$

2.2.26 Basis: 10 tons at 6 ft/s

$$\text{KE} = \frac{1}{2} m v^2 = \frac{1}{2} \left| \frac{20,000 \text{ lb}_m}{32.2(\text{ft})(\text{lb}_m)} \right| \left(\frac{6 \text{ ft}}{\text{s}} \right)^2 \left| \frac{1(\text{s}^2)(\text{lb}_f)}{32.2(\text{ft})(\text{lb}_m)} \right| = \boxed{11,200(\text{ft})(\text{lb}_f)}$$

2.2.27 Basis: 1 mRNA

$$\frac{1 \text{ mRNA}}{13.6 \text{ protein molecules formed per min per nRNA}} = \frac{3x \text{ ribonucleotides}}{\text{nRNA}} \left| \frac{1 \text{ active ribosome}}{264 \text{ ribonucleotides}} \right| \left| \frac{1200 \text{ amino acids}}{\text{min-active ribosome}} \right| \left| \frac{\text{protein}}{x \text{ amino acids}} \right| =$$

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Section 2.2.1 Temperature**2.2.28**

$$\begin{aligned}
 T_K &= -10 + 273 = 263\text{K} \\
 T^{\circ}\text{F} &= -10(1.8) + 32 = 14^{\circ}\text{F} \\
 T^{\circ}\text{R} &= 14 + 460 = 474^{\circ}\text{R}
 \end{aligned}$$

2.2.29

Yes, if the temperature scale is a linear relative one ($^{\circ}\text{C}$, $^{\circ}\text{F}$), or a logarithmic scale ($\ln 1^{\circ}$ is zero). No, if the scale is absolute, but read J. Wisniak, *J. Chem. Educ.*, **77**, 518-522 (2000) for a different conclusion.

2.2.30

$$C_p = 8.41 + \underbrace{2.4346 \times 10^{-5} T_K}_{\left(2.4346 \times 10^{-5} \frac{\text{J}}{(\text{gmol})(\text{K})^2} \right) (T_K)}$$

Substitute $1.8 T_K = T^{\circ}\text{R}$

$$C_p = 8.41 + 2.4346 \times 10^{-5} \frac{\text{J}}{(\text{gmol})(\text{K})^2} \left(\frac{T_{\circ R}}{1.8} \right)$$

$$= \boxed{8.41 + 1.353 \times 10^{-5} T_{\circ R}}$$

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2.2.31

$$a) \quad \frac{10^{\circ}\text{C}}{1.0^{\circ}\text{C}} \left| \frac{1.8^{\circ}\text{F}}{1.0^{\circ}\text{C}} \right| + 32 = \boxed{50^{\circ}\text{F}}$$

$$b) \quad \frac{10^{\circ}\text{C}}{1.0^{\circ}\text{C}} \left| \frac{1.8^{\circ}\text{F}}{1.0^{\circ}\text{C}} \right| + 32 + 460^{\circ}\text{R} = \boxed{510^{\circ}\text{R}}$$

$$c) \quad \frac{-25^{\circ}\text{F} - 32^{\circ}\text{F}}{1.8} \left| \frac{1.0^{\circ}\text{C}}{1.8^{\circ}\text{F}} \right| + 273\text{K} = \boxed{241.3\text{K}}$$

$$d) \quad \frac{150\text{K}}{1.0\text{K}} \left| \frac{1.8^{\circ}\text{R}}{1.0\text{K}} \right| = \boxed{270^{\circ}\text{R}}$$

2.2.32 First multiply the RHS of the equation so that

Btu	1054.8J	1 lb mol	1.8°F	1°C
(lbmol)(°F)	1 Btu	454 gmol	1.0°C	1K

$$= 4.182 \frac{\text{J}}{(\text{gmol})(\text{K})} \quad \text{TBEXAM.COM}$$

and substitute $T^{\circ}\text{F} = 1.8T^{\circ}\text{C} + 32$

$$C_p = \left[8.488 + 0.5757 \times 10^{-2} (1.8T_c + 32) - 0.2159 \times 10^{-5} (1.8T_c + 32)^2 + 0.3059 \times 10^{-9} (1.8T_c + 32)^3 \right] 4.182 \frac{\text{J}}{(\text{gmol})(\text{K})}$$

Simplifying,

$$C_p = 36.05 + 0.0447T - 0.2874 \times 10^{-4} T^2 + 0.7424 \times 10^{-8} T^3$$

Section 2.3 Equations and Units**2.3.1**

Solving for the constant term in the equation, $4.8 = \frac{Q}{Wh^{1.5}} = \frac{\text{gpm}}{\left| \frac{\text{in}}{\text{in}^{1.5}} \right|} = \text{gpm in}^{-2.5}$

2.3.2

From the back inside cover, $R = \frac{10.73 \text{ psia ft}^3}{\text{lbmol}^\circ \text{R}} \left| \frac{7.481 \text{ gal}}{\text{ft}^3} \right| \left| \frac{\text{lbmol}}{454.3 \text{ gmol}} \right| \left| \frac{9^\circ \text{R}}{5\text{K}} \right| = 0.3180 \text{ psia gal gmol}^{-1} \text{ K}^{-1}$

2.3.3

Solving for M the constant term in the equation recognizing that a radian is dimensionless,

$$M = \frac{TL}{\theta S} = \frac{\cancel{\text{N}} \text{ m}}{\cancel{\text{N}}} \left| \frac{\text{m}}{\cancel{\text{N}}} \right| \frac{\text{m}^2}{\cancel{\text{N}}} = \text{m}^4$$

2.3.4

$$P = \dot{m}gh =$$

$$\frac{4.3 \times 10^6 \text{ gal}}{\text{min}} \left| \frac{9.801 \cancel{\text{m}}}{\cancel{\text{s}}^2} \right| \left| \frac{180 \cancel{\text{m}}}{\cancel{\text{gal}}} \right| \left| \frac{3.875 \times 10^{-3} \cancel{\text{m}}^3}{\cancel{\text{gal}}} \right| \left| \frac{1000 \cancel{\text{kg}}}{\cancel{\text{m}}^3} \right| \left| \frac{\cancel{\text{J}} \cancel{\text{s}}^2}{\cancel{\text{kg}} \cancel{\text{m}}^2} \right| \left| \frac{\cancel{\text{W}} \cancel{\text{s}}}{\cancel{\text{J}}} \right| \left| \frac{\text{h}}{3600 \cancel{\text{s}}} \right| \left| \frac{\text{TW}}{10^{12} \cancel{\text{W}}} \right| \left| \frac{60 \cancel{\text{min}}}{\cancel{\text{h}}} \right| \left| \frac{24 \cancel{\text{h}}}{\cancel{\text{d}}} \right| \left| \frac{365 \cancel{\text{d}}}{\text{y}} \right|$$

$$= 4.3 \text{ TW h y}^{-1}$$

2.3.5

$$\frac{\pi 15^2 \cancel{\text{ft}}^2}{4} \left| \frac{30 \cancel{\text{ft}}}{\cancel{\text{ft}}^3} \right| \left| \frac{7.481 \cancel{\text{gal}}}{\cancel{\text{ft}}^3} \right| \left| \frac{\text{car}}{15 \cancel{\text{gal}}} \right| = 2600 \text{ cars}$$

2.3.6

$$C_D = \frac{2F}{\rho v^2 A} = \frac{\text{lb}_f}{\text{lb}_m} \left| \frac{\cancel{\text{ft}}^3}{\cancel{\text{lb}_m}} \right| \left| \frac{\text{s}^2}{\cancel{\text{ft}}^2} \right| \left| \frac{\text{ft}^2}{\cancel{\text{ft}}^2} \right| = \text{lb}_f \text{ s}^2 \text{ lb}_m^{-1} \text{ ft}^{-1}$$

Note that if the right hand side is multiplied by $g_c C_D$ becomes dimensionless.

2.3.7

$$G = F \frac{r^2}{Mm} = \frac{\text{N}}{\text{kg}} \left| \frac{\text{m}^2}{\cancel{\text{kg}}} \right| \left| \frac{\text{kg}}{\cancel{\text{kg}}} \right| = \text{N m}^2 \text{ kg}^{-2}$$

2.3.8

- a₁. A is in g/cm³
 a₂. B is in g/(cm³)(°C)
 a₃. Since the exponent of e must be dimensionless
 C is in atm⁻¹

$$b_1 \quad A = \frac{1.096 \text{ g}}{\text{cm}^3} \left| \frac{(30.48)^3 \text{ cm}^3}{\text{ft}^3} \right| \frac{1 \text{ lb}_m}{454 \text{ g}} = \boxed{68.4 \frac{\text{lb}_m}{\text{ft}^3}}$$

$$b_2 \quad B = \frac{0.00086 \text{ g}}{(\text{cm}^3)(^\circ\text{C})} \left| \frac{(30.48)^3 \text{ cm}^3}{\text{ft}^3} \right| \frac{1 \text{ lb}_m}{454 \text{ g}} \frac{1^\circ\text{C}}{1.8^\circ\text{R}} = \boxed{0.0298 \frac{\text{lb}_m}{(\text{ft}^3)(^\circ\text{R})}}$$

$$b_3 \quad C = \frac{0.000953}{\text{atm}} \left| \frac{1 \text{ atm}}{14.7 \text{ lb}_f/\text{in}^2} \right| = \boxed{0.0000648 \frac{1}{\text{lb}_f/\text{in}^2}}$$

2.3.9

Introduce the units. The net units are the same on both sides of the equation.

$$(\text{ft})(\text{ft})^{1.5} \left(\frac{\text{ft}}{\text{s}^2} \right)^{1/2} = \frac{\text{ft}^3}{\text{s}}$$

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2.3.10

$$\text{No.} \quad q = 0.6(2\text{m}^2) \left[\frac{(2)}{\text{s}^2} \left| \frac{9.8\text{m}}{\text{kg}} \right| \frac{10^{-3}\text{m}}{(s^2)(\text{m}^2)} \left| \frac{50 \times 10^3 (\text{kg})(\text{m})}{1 - \left(\frac{2}{5} \right)^2} \right| \right]^{1/2}$$

The net units on the right-hand side of the equation are

$$\text{m}^2 \left[\frac{\text{m}^3}{\text{s}^4} \right]^{1/2} \neq \frac{\text{m}^3}{\text{s}}$$

Consequently, the formula will not yield 80.8 m³/s; presumably in the formula the g should be g_c for use in the AE system.

2.3.11 $Q = 0.61S \sqrt{(2\Delta p)/\rho}$ Assume hole is open to atmosphere.

$$\Delta p = \frac{144 \text{ in}^2}{1 \text{ ft}^2} \left[\frac{23 \text{ lb}_f}{\text{in}^2} + \frac{73 \text{ in gas.}}{1 \text{ gas}} \left| \frac{0.703 \text{ H}_2\text{O}}{12 \text{ in}} \right| \frac{1 \text{ ft}}{33.91 \text{ ft H}_2\text{O}} \frac{14.7 \text{ lb}_f}{\text{in}^2} \right]$$

$$= 3,579 \text{ lb}_f/\text{ft}^2$$

$$\rho = \frac{0.703 \frac{\text{lb}}{\text{ft}^3}}{1 \text{ lb}/\text{ft}^3 \text{H}_2\text{O}} \left| \frac{14.7 \text{ lb H}_2\text{O}}{62.4 \text{ ft}^3 \text{H}_2\text{O}} \right| = 43.87 \frac{\text{lb}_m}{\text{ft}^3} \text{N}$$

$$S = \pi \left(\frac{1}{(4)12} \right)^2 = 3.41 \times 10^{-4} \text{ ft}^2$$

$$Q = (3600)(0.61)(3.41 \times 10^{-4}) \sqrt{(2)(3579)g_c / 43.87} = \boxed{54 \frac{\text{ft}^3}{\text{hr}}}$$

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2.3.12 a. $Z = 1 + \rho B + \rho^2 C + \rho^3 D$

	Units
B	$\text{cm}^3 / \text{g mol}$
C	$(\text{cm}^3 / \text{g mol})^2$
D	$(\text{cm}^3 / \text{g mol})^3$

b. $Z = 1 + \rho^* B^* + (\rho^*)^2 C^* + (\rho^*)^3 D^*$

	Units
B*	$\text{ft}^3 / \text{lb}_m$
C*	$(\text{ft}^3 / \text{lb}_m)^2$
D*	$(\text{ft}^3 / \text{lb}_m)^3$

If B is the original coefficient, B* is obtained by multiplying B by conversion factors. Let MW be the molecular weight of the compound.

$$B^* \frac{\text{ft}^3}{\text{lb}_m} = \frac{B \text{ cm}^3}{\text{g mol}} \left| \left(\frac{1 \text{ ft}}{30.48 \text{ cm}} \right)^3 \right| \left| \frac{1 \text{ g mol}}{\text{MW g}} \right| \left| \frac{454 \text{ g}}{1 \text{ lb}_m} \right| = \boxed{B \frac{0.016}{\text{MW}}}$$

$$C^* \left(\frac{\text{ft}^3}{\text{lb}_m} \right)^2 = C \left(\frac{\text{cm}^3}{\text{g mol}} \right)^2 \left| \left(\frac{1 \text{ ft}}{30.48 \text{ cm}} \right)^6 \right| \left| \left(\frac{1 \text{ g mol}}{\text{MW g}} \right)^2 \right| \left| \left(\frac{454 \text{ g}}{1 \text{ lb}_m} \right)^2 \right| = \boxed{C \frac{2.57 \times 10^{-4}}{\text{MW}^2}}$$

$$D^* \left(\frac{\text{ft}^3}{\text{lb}_m} \right)^3 = \boxed{D \frac{4.096 \times 10^{-6}}{\text{MW}^3}}$$

2.3.13

$$u \left[\frac{\text{m}}{\text{s}} \right] = k[1] \left[\left(\frac{\tau}{\rho} \right)^{1/2} \left(\frac{\text{N}}{\text{m}^2} \right)^{1/2} \left(\frac{\text{m}^3}{\text{kg}} \right)^{1/2} \right]$$

To get u in ft/s, substitute for τ and for ρ , and multiply both sides of the equation by 3.281 ft/1 m (k is dimensionless).

$$\tau \frac{\text{N}}{\text{m}^2} = \frac{\tau' \text{lb}_f}{\text{ft}^2} \left| \left(\frac{3.281 \text{ ft}}{1 \text{ m}} \right)^2 \right| \frac{1 \text{ N}}{0.2248 \text{ lb}_f}$$

$$\rho \frac{\text{kg}}{\text{m}^3} = \frac{\rho' \text{lb}_m}{\text{ft}^3} \left| \left(\frac{3.281 \text{ ft}}{1 \text{ m}} \right)^3 \right| \frac{1 \text{ kg}}{0.454 \text{ lb}_m}$$

$$u' = 2.57 k \left(\frac{\tau'}{\rho'} \right)$$

2.3.14

Place units for the symbols in the given equation, and equate the units on the left- and right-hand sides of the equation by assigning appropriate units to the coefficient 0.943.

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$$\begin{array}{ccc} \text{LHS} & & \text{RHS} \\ \frac{\text{Btu}}{(\text{hr})(\text{ft}^2)(\Delta^\circ \text{F})} & \stackrel{?}{=} & \left[\left(\frac{\text{Btu}}{(\text{hr})(\text{ft})(\Delta^\circ \text{F})} \right)^3 \left(\frac{\text{lb}_m}{\text{ft}^3} \right)^2 \left| \frac{\text{ft}}{(\text{hr})^2} \right| \left| \frac{\text{Btu}}{\text{lb}_m} \right| \left| \frac{(\text{hr})(\text{ft})}{\text{lb}_m} \right| \left| \frac{1}{\Delta^\circ \text{F}} \right| \right]^{1/4} \end{array}$$

The units are the same on the right and left so that 0.943 has no units associated with it.

2.3.15

$$\eta = \frac{\text{numerator}}{\text{denominator}}$$

$$\text{Numerator} = Y_{x/s}^c \gamma_b \Delta H_{b/e^-}^c$$

$$= \left(\frac{\text{mol cell C}}{\text{mole substrate C}} \right) \left(\frac{\text{e}^- \text{ equiv.}}{\text{mol cell C}} \right) \left(\frac{\text{energy}}{\text{mol e}^- \text{ equiv.}} \right)$$

$$= \frac{\text{energy}}{\text{mol substrate C}} \quad (1)$$

$$\begin{aligned}
 \text{Denominator} &= \Delta H_{\text{cat}}^c \\
 &= \frac{\text{energy}}{\text{mol substrate C}} \quad (2) \\
 \eta &= \frac{(1)}{(2)} = \frac{\text{energy}}{\text{energy}}
 \end{aligned}$$

There is no missing conversion factor.
What the author claimed about the units is correct.

2.3.16

For dimensional consistency:
B – absolute temperature in either °R or K
C – absolute temperature in either °R or K
A – dimensionless

In most cases, the argument of a logarithm function should be dimensionless, but in this case it will not be. Therefore, the numerical values of A, B, and C will depend upon the units used for temperature and the units used for p^* .

2.3.17

The equation is

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$$\Delta p = 4f\rho \left[(v^2 / 2g) (L/D) \right]$$

The units on the right-hand side (with f dimensionless) in SI are

$$\frac{\rho \frac{\text{kg}}{\text{m}^3}}{\left(\frac{\frac{\text{m}^2}{\text{s}^2}}{\frac{(\text{kg})(\text{m})}{\text{s}^2}} \right) \frac{\text{m}}{\text{m}}} \rightarrow \frac{1}{\text{m}^2}$$

Hence, the equation is not dimensionally consistent because Δp has the units of N/m^2 .
If g is replaced with g , the units would be correct.

2.3.18 First multiply the RHS of the equation so that

Btu	1054.8J	1 lb mol	1.8°F	1°C
(lbmol)(°F)	1 Btu	454 gmol	1.0°C	1K

$$= 4.182 \frac{\text{J}}{(\text{gmol})(\text{K})}$$

and substitute $T^{\circ}\text{F} = 1.8T^{\circ}\text{C} + 32$

$$C_p = [8.488 + 0.5757 \times 10^{-2}(1.8T_{\text{c}} + 32) - 0.2159 \times 10^{-5}(1.8T_{\text{c}} + 32)^2 + 0.3059 \times 10^{-9}(1.8T_{\text{c}} + 32)^3] 4.182 \frac{\text{J}}{(\text{gmol})(\text{K})}$$

Simplifying,

$$C_p = 36.05 + 0.0447T - 0.2874 \times 10^{-4} T^2 + 0.7424 \times 10^{-8} T^3$$

2.3 Measurement Errors and Significant Figures

2.4.1

- (a) 1.24×10^1 : 3 significant figures (f) 2.000×10^3 : 4 significant figures
 (b) 2.3×10^{-3} : 2 significant figures (g) $9. \times 10^{-3}$: 1 significant figure
 (c) $1. \times 10^2$: 1 significant figure (h) 2.30×10^{-3} : 3 significant figures
 Or 1.0×10^2 : 2 significant figures
 Or 1.00×10^2 : 3 significant figures
 (d) 2.234×10^4 : 4 significant figures (i) 7.78×10^2 : 3 significant figures
 Or 2.2340×10^4 : 5 significant figures
 (e) 2.0001×10^{-1} : 5 significant figures (j) 7.780×10^2 : 4 significant figures

2.4.2

- (a) 3 significant figures: $\pm 0.1\%$ (f) 4 significant figures: $\pm 0.01\%$
 (b) 2 significant figures: $\pm 1\%$ (g) 1 significant figure: $\pm 10\%$
 (c) 1 significant figure: $\pm 10\%$ (h) 3 significant figures: $\pm 0.1\%$
 Or 2 significant figures: $\pm 1\%$
 Or 3 significant figures: $\pm 0.1\%$
 (d) 4 significant figures: $\pm 0.01\%$ (i) 3 significant figures: $\pm 0.1\%$
 Or 5 significant figures: $\pm 0.001\%$ (j) 4 significant figures: $\pm 0.01\%$
 (e) 5 significant figures: $\pm 0.001\%$

2.4.3

- (a) 1.1×10^{-3} : 2 significant figures (f) 4.354×10^5 : 4 significant figures
 Or 4.3540×10^5 : 5 significant figures
 Or 4.35400×10^5 : 6 significant figures
 (b) $5. \times 10^3$: 1 significant figure (g) 1.0010×10^2 : 5 significant figure
 Or 5.0×10^3 : 2 significant figures

Or 5.00×10^3 : 3 significant figures

Or 5.000×10^3 : 4 significant figures

(c) 2.3001×10^0 : 5 significant figures

(d) 8.877×10^5 : 4 significant figures

Or 8.8770×10^5 : 5 significant figures

(e) 8.87700×10^5 : 6 significant figures

(h) 5.61×10^7 : 3 significant figures

(i) 1.000×10^0 : 4 significant figures

(j) $1. \times 10^1$: 1 significant figures

Or 1.0×10^1 : 2 significant figures

2.4.4

(a) 2 significant figures: $\pm 1\%$

(f) 4 significant figures: $\pm 0.01\%$

Or 5 significant figures: $\pm 0.001\%$

Or 6 significant figures: $\pm 0.0001\%$

(g) 5 significant figures: $\pm 0.001\%$

(b) 1 significant figure: $\pm 10\%$

Or 2 significant figures: $\pm 1\%$

Or 3 significant figures: $\pm 0.1\%$

Or 4 significant figures: $\pm 0.01\%$

(c) 5 significant figures: $\pm 0.001\%$

(h) 3 significant figures: $\pm 0.1\%$

(d) 4 significant figures: $\pm 0.01\%$

(i) 4 significant figures: $\pm 0.01\%$

Or 5 significant figures: $\pm 0.001\%$

(e) 6 significant figures: $\pm 0.0001\%$

(j) 1 significant figures: $\pm 10\%$

Or 2 significant figures: $\pm 1\%$

2.4.5

Two because any numbers added to the right-hand side of the decimal point in 10 are irrelevant.

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2.4.6

The sum is 1287.1430. Because 1234 has only 4 significant figures to the left of an implied decimal point, the answer should be 1287 (no decimal point).

2.4.7 The number of significant figures to the right of the decimal point is 1 (from 210.0m); hence, the sum of 215.110 m should be rounded to 215.1 m.

2.4.8 A calculator gives 569.8269 000, but you should truncate to 4 significant figures, or 569.8 cm².

2.4.9 Two significant figures (based on 6.3). Use 4.8×10^3 .

2.4.10 Step 1: The product 1.3824 is rounded off to 1.4.

Step 2: Calculate errors.

For absolute error, the product 1.4 means 1.4 ± 0.05 .

Thus $\frac{0.05}{1.4} \times 100\% = 3.6\%$ error

Similarly, 3.84 has $\frac{0.005}{3.84} \times 100\% = 0.13\%$ error

and 0.36 has $\frac{0.005}{0.36} \times 100\% = 1.4\%$ error

Total 2.7% error

2.5 Validating Solutions

2.5.1

a. $6 \times 4 / 3 = 8$ Exact solution = 7.704

b. 1.45 The second term is much smaller than the first term. Exact solution = 1.423

c. $3 \times 4 \times 2^8 / 3 = 4 \times 8 = 32$ Exact solution = 31.54

d. $8 \times 3 \times (16 \times 50 - 25) / 3 = 8(800 - 25) = 6400 - 200 = 6200$ Exact solution = 6767

e. $88.8 \times (1+1) / 2 = 88.8$ Exact solution = 87.47

2.6 Mass, Moles, and Density

2.6.1 Choosing a Basis

2.6.1 (a) A gas requires a convenient basis of 1 or 100 g moles or kg moles (if using SI units).

(b) A gas requires a convenient basis of 1 or 100 lb moles (if using AE units).

- (c) Use 1 or 100 kg of coal, or 1 or 100 lb of coal because the coal is a solid and mass is a convenient basis.
- (d) Use 1 or 100 moles (SI or AE) as a convenient basis as you have a gas.
- (e) Use 1 or 100 moles (SI or AE) as a convenient basis as you have a gas.

2.6.2 Since the mixture is a gas, use 1 or 100 moles (SI or AE) as the basis.

2.6.3 Pick one day as a basis that is equivalent to what is given—two numbers:

- (a) 134.2 lb C1 (b) 10.7×10^6 gal water.

2.6.2 The Mole and Molecular Weight

2.6.4

a)
$$\frac{4 \text{ g mol mg Cl}_2}{\text{gmol MgCl}_2} \left| \frac{(95.23)\text{g MgCl}_2}{\text{gmol MgCl}_2} \right| = \boxed{380.9 \text{ g}}$$

b)
$$\frac{2 \text{ lb mol C}_3\text{H}_8}{\text{lb mol C}_3\text{H}_8} \left| \frac{(44.09)\text{lb C}_3\text{H}_8}{\text{lb mol C}_3\text{H}_8} \right| \frac{454\text{g C}_3\text{H}_8}{1 \text{ lb C}_3\text{H}_8} = \boxed{4 \times 10^4 \text{ g C}_3\text{H}_8}$$

c)
$$\frac{16 \text{ g N}_2}{\text{gmol N}_2} \left| \frac{\text{gmol N}_2}{(28.02)\text{g N}_2} \right| \frac{1 \text{ lb mol N}_2}{454 \text{ gmol N}_2} = \boxed{1.26 \times 10^{-3} \text{ lb mol N}_2}$$

(d)
$$\frac{3 \text{ lb C}_2\text{H}_6\text{O}}{\text{lb mol C}_2\text{H}_6\text{O}} \left| \frac{1 \text{ lb mol C}_2\text{H}_6\text{O}}{(46.07) \text{ lb C}_2\text{H}_6\text{O}} \right| \frac{454 \text{ g mol}}{1 \text{ lb mol}} = \boxed{29.56 \text{ g mol C}_2\text{H}_6\text{O}}$$

2.6.5

$$(a) \quad \frac{16.1 \text{ lb mol HCl}}{1 \text{ lb mol HCl}} \left| \frac{36.5 \text{ lb HCl}}{1 \text{ lb mol HCl}} \right| = \boxed{588 \text{ lb HCl}}$$

$$(b) \quad \frac{19.4 \text{ lb mol KCl}}{1 \text{ lb mol KCl}} \left| \frac{74.55 \text{ lb KCl}}{1 \text{ lb mol KCl}} \right| = \boxed{1466 \text{ lb KCl}}$$

$$(c) \quad \frac{11.9 \text{ g mol NaNO}_3}{1 \text{ g mol NaNO}_3} \left| \frac{85 \text{ g NaNO}_3}{1 \text{ g mol NaNO}_3} \right| \left| \frac{2.20 \times 10^{-3} \text{ lb}}{1 \text{ g}} \right| = \boxed{2.23 \text{ lb NaNO}_3}$$

$$(d) \quad \frac{164 \text{ g mol SiO}_2}{1 \text{ g mol SiO}_2} \left| \frac{60.1 \text{ g SiO}_2}{1 \text{ g mol SiO}_2} \right| \left| \frac{2.20 \times 10^{-3} \text{ lb}}{1 \text{ g}} \right| = \boxed{21.7 \text{ lb SiO}_2}$$

2.6.6

Basis: 100 g of the compound

<u>comp.</u>	<u>g</u>	<u>MW</u>	<u>g mol</u>	<u>Ratio of Atoms</u>
C	42.11	12	3.51	1.09
O	51.46	16	3.22	1
H	6.43	1.008	<u>6.38</u>	2
			13.11	

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Multiply by 11 to convert the ratios into integers

The formula becomes C₁₂O₁₁H₂₂.

Checking MW: 12(12) + 11(16) + 22(1.008) = 342 (close enough)

2.6.7 Vitamin A, $C_{20}H_{30}O$, Mol Wt.: 286 Vitamin C, $C_6H_8O_6$, mol. wt: 176

$$a. \quad \text{Vitamin A} = \frac{2.00 \text{ g mol}}{1 \text{ g mol}} \left| \frac{286 \text{ g}}{454 \text{ g}} \right| \frac{1 \text{ lb}}{1 \text{ lb}} = \boxed{1.26 \text{ lb}}$$

$$\frac{16 \text{ g}}{454 \text{ g}} \left| \frac{1 \text{ lb}}{1 \text{ lb}} \right| = 0.0352 \text{ lb}$$

$$\text{Vitamin C} = \frac{2.00 \text{ g mol}}{1 \text{ g mol}} \left| \frac{176 \text{ g}}{454 \text{ g}} \right| \frac{1 \text{ lb}}{1 \text{ lb}} = \boxed{0.775 \text{ lb}}$$

$$\frac{16 \text{ g}}{454 \text{ g}} \left| \frac{1 \text{ lb}}{1 \text{ lb}} \right| = \boxed{0.0352 \text{ lb}}$$

$$b. \quad \text{Vitamin A} = \frac{1.00 \text{ lb mol}}{1 \text{ lb mol}} \left| \frac{286 \text{ lb}}{454 \text{ g}} \right| \frac{454 \text{ g}}{1 \text{ lb}} = \boxed{130,000 \text{ g}}$$

$$\text{Vitamin C} = \frac{1.00 \text{ lb mol}}{1 \text{ lb mol}} \left| \frac{176 \text{ lb}}{454 \text{ g}} \right| \frac{454 \text{ g}}{1 \text{ lb}} = \boxed{79,900 \text{ g}}$$

$$\text{For both} \quad \frac{12 \text{ lb}}{1 \text{ lb}} \left| \frac{454 \text{ g}}{1 \text{ lb}} \right| = \boxed{5450 \text{ g}}$$

2.6.8

$$\frac{1 \text{ kg}}{5.2 \text{ m}^3} \left| \frac{1160 \text{ m}^3}{\text{kg mol}} \right| = 223.1 \text{ kg/kg mol}$$

2.6.9 Mass fraction to mole fraction:

$$x_1 = \frac{\frac{\omega_1}{MW_1}}{\frac{\omega_1}{MW_1} + \frac{(1-\omega_1)}{MW_2}}$$

Mole fraction to mass fraction

$$\omega_1 = \frac{x_1 MW_1}{(x_1)(MW_1) + (1 - x_1)(MW_2)}$$

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T
B
E
X
A
M
.
C
O
M

2.6.10

Basis: 100 kg mol gas

<u>Comp.</u>	<u>Mol % = mol</u>	<u>MW</u>	<u>kg</u>
CH ₄	30	16	480
H ₂	10	2	20
N ₂	<u>60</u>	28	<u>1680</u>
Total	100		2180

21.8 kg
kg mol

2.6.11

Basis: 100 g mol gas

<u>Comp.</u>	<u>mol = %</u>	<u>MW</u>	<u>g</u>
CO ₂	19.3	44	849.2
N ₂	72.1	28	2018.8
O ₂	6.5	32	208.0
H ₂ O	<u>2.1</u>	18	<u>37.8</u>
	100.0		3113.8

$$\text{Avg. mol. wt} = \frac{3113.8}{100.0} = \boxed{31.138}$$

2.6.12

Basis: 100 lb mol

<u>Comp.</u>	<u>% = mol</u>	<u>MW</u>	<u>lb</u>
CO ₂	16	44	2640
CO	10	28	280
N ₂	30	28	<u>840</u>
			3760

$$\text{Avg. MW} = 37.6 \text{ lb/lb mol}$$

2.6.13(a) $10 \times 1000 \times 6.022 \times 10^{23} = 6.022 \times 10^{27}$ molecules of Bz(b) $10 \times 2.2046 = 22.046$ lb mol Bz(c) $78 \times 22.046 = 1719.6$ lb Bz

(d) 10,000 gmol Bz

(e) 60,000 gmol H

(f) 60,000 gmol C

Section 2.6.3 Density and Specific Gravity

2.6.14

$$\frac{100 \text{ lb}_m}{62.4 \times 5.25 \text{ lb}_m} \left| \frac{\text{ft}^3}{\text{ft}^3} \right| = 0.0305 \text{ ft}^3$$

2.6.15 Basis: 1000 lb oil

$$\frac{0.926 \frac{\text{lb oil}}{\text{ft}^3}}{1.00 \frac{\text{lb H}_2\text{O}}{\text{ft}^3}} \left| \frac{62.4 \frac{\text{lb H}_2\text{O}}{\text{ft}^3}}{\text{ft}^3} \right| = 57.78 \frac{\text{lb oil}}{\text{ft}^3}$$

$$\frac{1000 \text{ lb oil}}{57.78 \text{ lb oil}} \left| \frac{1 \text{ ft}^3 \text{ oil}}{1 \text{ ft}^3} \right| \left| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \right| = 129.5 \text{ gal}$$

2.6.16 Basis: 10,010 lb

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$$\frac{10,010 \text{ lb}}{8.80 \text{ lb}} \left| \frac{1 \text{ gal}}{\text{gal}} \right| \left| \frac{0.134 \text{ ft}^3}{\text{gal}} \right| = \boxed{152 \text{ ft}^3}$$

2.6.17

Basis: 1 g mol each compound

	<u>g mol</u>	<u>mw</u>	<u>g</u>	<u>ρ (g/cm³)</u>	<u>V (cm³)</u>
Pb	1	207.21	207.21	11.33	18.3
Zn	1	65.38	65.38	7.14	9.16
C	1	12.01	12.01	2.26	5.31

$$\hat{V} = \frac{\text{mass (g)}}{\text{density (g/cm}^3\text{)}}$$

Set 2 is the correct one.

Section 2.7.2 Pressure and Hydrostatic Head

2.7.1

Basis: 15cm³ water

$$a. \quad m = \rho V = \frac{1000 \text{ kg}}{\text{m}^3} \left| \frac{10 \text{ m}}{\text{m}} \right| \left| \frac{10 \text{ m}}{\text{m}} \right| \left| \frac{0.15 \text{ m}}{\text{m}} \right| = \boxed{15,000 \text{ kg}}$$

$$b. \quad \frac{F}{A} = \frac{m g}{A} = \frac{15,000 \text{ kg}}{\text{m}^2} \left| \frac{9.80 \text{ m}}{\text{s}^2} \right| \left| \frac{1 \text{ N}}{1 \frac{(\text{kg})(\text{m})}{\text{s}^2}} \right| \left| \frac{1 \text{ Pa}}{\text{N}} \right| = 1470 \text{ Pa}$$

$$= \boxed{1.47 \text{ kPa}}$$

$$\frac{1.470 \text{ kPa}}{\text{Pa}} \left| \frac{1 \text{ atm}}{101.3 \text{ kPa}} \right| \left| \frac{14.7 \text{ psi}}{\text{atm}} \right| = \boxed{0.21 \text{ psi}}$$

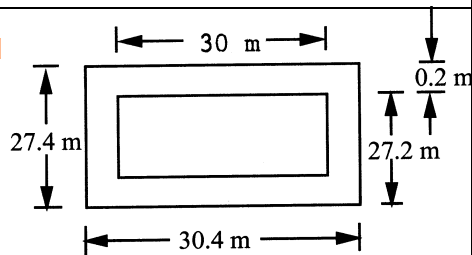
$$\text{or} \quad \frac{15 \text{ cm H}_2\text{O}}{\text{cm}} \left| \frac{1 \text{ in.}}{2.54 \text{ cm}} \right| \left| \frac{1 \text{ ft}}{12 \text{ in.}} \right| \left| \frac{14.696 \text{ psi}}{33.91 \text{ ft H}_2\text{O}} \right| = 0.21$$

2.7.2

$$\rho_{\text{concrete}} = 2080 \text{ kg/m}^3$$

$$\rho_{\text{water}} = 1000 \text{ kg/m}^3$$

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Volume of concrete:

Sides

$$V_s = \frac{5 \text{ m}}{\text{m}} \left| \frac{30.2 \text{ m}}{\text{m}} \right| \left| \frac{200 \text{ mm}}{1000 \text{ mm}} \right| \left| \frac{1 \text{ m}}{1000 \text{ mm}} \right| \left| \frac{2 \text{ sides}}{1} \right| = 60.4 \text{ m}^3$$

Ends

$$V_e = \frac{5 \text{ m}}{\text{m}} \left| \frac{27.2 \text{ m}}{\text{m}} \right| \left| \frac{200 \text{ mm}}{1000 \text{ mm}} \right| \left| \frac{1 \text{ m}}{1000 \text{ mm}} \right| \left| \frac{2 \text{ ends}}{1} \right| = 54.4 \text{ m}^3$$

Floor

$$V_f = \frac{27.4 \text{ m}}{\text{m}} \left| \frac{30.4 \text{ m}}{\text{m}} \right| \left| \frac{200 \text{ mm}}{1000 \text{ mm}} \right| \left| \frac{1 \text{ m}}{1000 \text{ mm}} \right| = 166.592 \text{ m}^3$$

$$\text{Total volume} = 281.392 \text{ m}^3$$

$$\text{Mass of concrete} = \frac{281.392 \text{ m}^3}{1} \left| \frac{2080 \text{ kg}}{\text{m}^3} \right| = 585,295$$

Volume of displaced water required to float:

$$\frac{586,543.36 \text{ kg}}{1} \left| \frac{1 \text{ m}^3 \text{ H}_2\text{O}}{1000 \text{ kg H}_2\text{O}} \right| = 586.543 \text{ m}^3$$

$$V = LWh \rightarrow h = \frac{V}{LW}$$

$$h = \frac{586.54 \text{ m}^3}{27.4 \text{ m} \times 30.4 \text{ m}} = \boxed{0.703 \text{ m}}$$

2.7.3 The pressure is a gauge pressure.

Basis: 50.0 psig

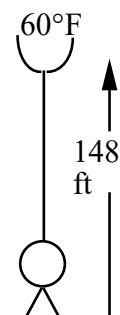
a.

$$\frac{50.0 \text{ psig}}{1} \left| \frac{33.91 \text{ ft H}_2\text{O}}{14.7 \text{ psia}} \right| = \boxed{115 \text{ ft}}$$

(difference)

b. No. Insufficient height.

Alternate solutions can be applying $\Delta p = \rho \Delta h g$.



2.7.4

$$\frac{\text{lb}_f}{\text{in.}^2} \left| \frac{\text{in.}^2}{1} \right| = \text{lb}_f \rightarrow \text{lb}_m \text{ in the AE system}$$

so the procedure is ok, although the unit conversion is ignored.

2.7.5 Basis: Dept = 1000 m $p = p_o + \rho gh$

$$p = 1 \text{ atm} +$$

$$\frac{1000 \text{ m}}{1} \left| \frac{1.024 \text{ g}}{\text{cm}^3} \right| \frac{9.8 \text{ m}}{\text{s}^2} \left| \frac{1 \text{ kg}}{10^3 \text{ g}} \right| \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \left| \frac{1 \text{ N}}{(\text{kg})(\text{m})/\text{s}^2} \right| \left| \frac{1 \text{ kPa}}{1 \text{ N}/(\text{kg})(\text{m})/\text{s}^2} \right| \frac{1 \text{ atm}}{1.013 \times 10^5 \text{ N/m}^2}$$

$$= \frac{100.1 \text{ atm}}{1 \text{ atm}} \left| \frac{101.3 \text{ kPa}}{1 \text{ atm}} \right| = \boxed{1.014 \times 10^4 \text{ kPa}}$$

Alternative solution:

$$A_{\text{Top}} = 730.62 \text{ m}^2 \text{ kPa}$$

2.7.6 (a) $p_{\text{ABS}} = p_{\text{Gauge}} + p_{\text{atm}}$

$$\left(\frac{22.4 \text{ lb}_f}{1 \text{ in.}^2} \right) \left| \frac{144 \text{ in.}^2}{1 \text{ ft}^2} \right| + \left(\frac{28.6 \text{ in. Hg}}{1} \right) \left| \frac{14.7 \text{ psia}}{29.92 \text{ in. Hg}} \right| \left| \frac{144 \text{ in.}^2}{1 \text{ ft}^2} \right| = \boxed{5250 \text{ lb}_f/\text{ft}^2}$$

$$(b) \left(\frac{22.4 \text{ psig}}{1} \right) \left| \frac{29.92 \text{ in. Hg}}{14.7 \text{ psia}} \right| + 28.6 \text{ in. Hg} = \boxed{74.2 \text{ in. Hg}}$$

$$(c) \left(\frac{22.4 \text{ psig}}{1} \right) \left| \frac{1.013 \times 10^5 \text{ N/m}^2}{14.7 \text{ psia}} \right| + \left(\frac{28.6 \text{ in. Hg}}{1} \right) \left| \frac{1.013 \times 10^5 \text{ N/m}^2}{29.92 \text{ in. Hg}} \right| = \boxed{2.51 \times 10^5 \text{ N/m}^2}$$

$$(d) \left(\frac{22.4 \text{ psig}}{1} \right) \left| \frac{33.91 \text{ ft H}_2\text{O}}{14.7 \text{ psia}} \right| + \left(\frac{28.6 \text{ in. Hg}}{1} \right) \left| \frac{33.91 \text{ ft H}_2\text{O}}{29.92 \text{ in. Hg}} \right| = \boxed{84.1 \text{ ft H}_2\text{O}}$$

2.7.7 Neither John is necessarily right. The pressure at the top of Pikes Peak is continually changing.

2.7.8 $\Delta p = \rho gh$

$$\text{a.} \quad = \frac{1 \text{ g}}{\text{cm}^3} \left| \frac{9.8 \text{ m}}{\text{s}^2} \right| \left| \frac{13.1 \text{ m}}{\text{m}} \right| \left| \frac{1 \text{ kg}}{1000 \text{ g}} \right| \left| \frac{(100 \text{ cm})^3}{\text{m}^3} \right| \left| \frac{\text{Pa}}{1 \text{ kg} / \text{m s}^2} \right| \left| \frac{1 \text{ kPa}}{1000 \text{ Pa}} \right|$$

$$= 128.4 \text{ kPa}$$

$$\text{b.} \quad \frac{F}{A} = \frac{mg}{A_{\text{Bottom}}} = \frac{\rho Vg}{A_{\text{Bottom}}} = \frac{\rho(\text{S.A.})(t)g}{A_{\text{Bottom}}}$$

$$A_{\text{Bottom}} = \frac{\pi}{4} D^2 = \frac{\pi}{4} \left| (30.5 \text{ m})^2 \right| = 730.62 \text{ m}^2$$

$$A_{\text{Top}} = 730.62 \text{ m}^2$$

$$A_{\text{side}} = \pi Dh = \pi(30.5 \text{ m})(13.1 \text{ m}) = 1255.2 \text{ m}^2$$

$$\text{S.A.} = A_{\text{Top}} + A_{\text{Bottom}} + A_{\text{Side}}$$

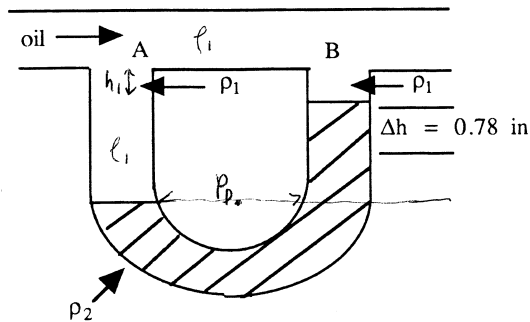
$$= (730.62 + 730.62 + 1255.22) \text{ m}^2 = 2716.46 \text{ m}^2$$

$$\frac{\rho(\text{S.A.})(t)g}{A} =$$

$$\frac{7.86 \text{ g}}{\text{cm}^3} \left| \frac{(100 \text{ cm}^3)}{\text{m}^3} \right| \left| \frac{2,716.46 \text{ m}^2}{\text{m}^2} \right| \left| \frac{9.35 \times 10^{-3} \text{ m}}{\text{m}} \right| \left| \frac{1 \text{ kg}}{1000 \text{ g}} \right| \left| \frac{1 \text{ Pa}}{1 \text{ kg} / \text{m s}^2} \right| \left| \frac{1 \text{ kPa}}{1000 \text{ Pa}} \right|$$

$$\frac{1 \text{ kg}}{1000 \text{ g}} \left| \frac{1 \text{ Pa}}{1 \text{ kg} / \text{m s}^2} \right| \left| \frac{1 \text{ kPa}}{1000 \text{ Pa}} \right| = \boxed{2.68 \text{ kPa}}$$

2.7.9



$$p_A + \rho_1 g h_1 + \rho_2 g \Delta h = P_D$$

$$p_B + \rho_1 g h_1 + \rho_2 g \Delta h = P_D$$

$$p_A - p_B = \rho_1 g h_1 + \rho_2 g \Delta h - \rho_1 g h_1 - \rho_1 g \Delta h$$

$$= \rho_2 g \Delta h - \rho_1 g \Delta h = g \Delta h (\rho_2 - \rho_1)$$

$$= \frac{9.8 \text{ m}}{\text{s}^2} \left| \frac{0.78 \text{ in}}{3.28 \text{ ft}} \right| \left| \frac{1 \text{ m}}{\text{cm}^3} \right| \left| \frac{13.546 - 0.91 \text{ g}}{1000 \text{ g}} \right|$$

$$\frac{1 \text{ ft}}{12 \text{ in}} \left| \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \right| \left| \frac{1 \text{ N}}{\text{m}^2} \right| \left| \frac{1 \text{ Pa}}{1 \text{ kg}} \right| \left| \frac{760 \text{ mm Hg}}{1013 \times 10^3 \text{ Pa}} \right|$$

$$= 18.4 \text{ mm Hg}$$

The pressure at A is higher than the pressure at B.

Alternate solution:

$$\Delta p = \frac{(0.78 \text{ in.})}{13.546} \left| \frac{760 \text{ mm Hg}}{29.92 \text{ in. Hg}} \right| = 18.5 \text{ mm Hg}$$

Section 2.7.4 Flow rate

2.7.10

2.7.11

2.7.12

2.7.13

Section 2.7.5 Concentration

2.7.14	<u>Component</u>	<u>g mol</u>	<u>mol fraction</u>	<u>MW</u>	<u>g</u>	<u>mass fraction</u>
	Na	1	0.20	23	23	0.22
	Cl	1	0.20	35.45	35.45	0.33
	O	<u>3</u>	<u>0.60</u>	16	<u>48</u>	<u>0.45</u>
		5			106.45	1.00

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2.7.15 Basis: 1 gal of solution.

Mass of solution:

$$\frac{1.0824 \text{ lb soln}}{\text{ft}^3 \text{ H}_2\text{O}} \left| \frac{62.4 \text{ lb H}_2\text{O}}{\text{ft}^3 \text{ H}_2\text{O}} \right| \frac{1 \text{ ft}^3}{7.481 \text{ gal}} \left| \frac{1 \text{ gal}}{1 \text{ gal}} \right| = \boxed{9.03 \text{ lb soln}}.$$

$$\text{Mass fraction KOH} = \frac{0.813 \text{ lb}}{9.03 \text{ lb}} = \boxed{0.09}$$

$$\text{Mass fraction H}_2\text{O} = 1 - 0.09 = \boxed{\frac{0.91}{1.00 \text{ Total}}}$$

2.7.16 Basis: 30 lb gas

<u>Comp.</u>	<u>lb</u>	<u>MW</u>	<u>lb mol</u>	<u>mol fr.</u>
CO ₂	20	44	0.455	0.56
N ₂	10	28	0.357	0.44
	30		0.812	1.00

2.7.17 a)

b)

c) Yes, because for solids and liquids the ratio in ppb is mass, whereas for gases the ratio is in moles.

2.7.18

On a paper-free basis, the total ppm are:

Brand A: 6060 ppm Brand B: 405 ppm

The respective mass fractions are:

The other entries are similar

	<u>Fe</u>	<u>Cu</u>	<u>Pb</u>
Brand A:	$\frac{1310}{6060} = 0.216$	$\frac{2000}{6060} = 0.330$	
	$\frac{2750}{6060} = 0.454$		
Brand B:	$\frac{350}{405} = 0.864$	$\frac{50}{405} = 0.123$	
	$\frac{5}{405} = 0.0123$		

$$V_s = \frac{5 \text{ m} | 30.2 \text{ m} | 200 \text{ mm} | 1 \text{ m} | 2 \text{ sides}}{1000 \text{ mm}} = 60.4 \text{ m}^3$$

Ends

$$V_e = \frac{5 \text{ m} | 27.2 \text{ m} | 200 \text{ mm} | 1 \text{ m} | 2 \text{ ends}}{1000 \text{ mm}} = 54.4 \text{ m}^3$$

Floor

$$V_f = \frac{27.4 \text{ m}}{1} \left| \frac{30.4 \text{ m}}{1} \right| \left| \frac{200 \text{ mm}}{1000 \text{ mm}} \right| \frac{1 \text{ m}}{1} = 166.592 \text{ m}^3$$

$$\text{Total volume} = 281.392 \text{ m}^3$$

$$\text{Mass of concrete} = \frac{281.392 \text{ m}^3}{1} \left| \frac{2080 \text{ kg}}{\text{m}^3} \right| = 585,295 \text{ kg}$$

Volume of displaced water required to float:

$$\frac{586,543.36 \text{ kg}}{1} \left| \frac{1 \text{ m}^3 \text{ H}_2\text{O}}{1000 \text{ kg H}_2\text{O}} \right| = 586.543 \text{ m}^3$$

$$V = LWh \rightarrow h = \frac{V}{LW}$$

$$h = \frac{586.54 \text{ m}^3}{1} \left| \frac{1}{27.4 \text{ m}} \right| \left| \frac{1}{30.4 \text{ m}} \right| = \boxed{0.703 \text{ m}}$$

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2.7.19 Basis: 190,000 ppm

$$\frac{190,000 \text{ g PCB}}{10^6} \times 100 = \boxed{19\%}$$

2.7.20

Basis: 100 g of the sample

The biomass sample is

g = % dry weight of cells

C	50.2
O	20.1
H	8.2
P	<u>3.0</u>
	95.5
other	<u>4.5</u>
Total	100.0

$$\frac{10.5 \text{ g cells}}{\text{g mol ATP}} \left| \frac{50.2 \text{ g C}}{100 \text{ g cells}} \right| \frac{1 \text{ g mol C}}{12 \text{ g C}} = 0.439 \text{ g mol C/g mol ATP}$$

2.7.21

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$$\text{a. } \frac{2 \times 10^7 \text{ disintegrations}}{\text{min}} \left| \frac{1 \text{ min}}{60} \right| \frac{1 \text{ curie}}{3 \times 10^{10} \text{ disintegrations/s}} \left| \frac{10^6 \mu \text{ curie}}{1 \text{ curie}} \right| = 11 \mu \text{ curie}$$

$$\text{b. } \frac{2 \times 10^7 \text{ disintegrations}}{\text{min}} \left| \frac{0.80}{1} \right| = \boxed{1.6 \times 10^7 \text{ cpm}}$$

2.7.22

The relation to use is

$$t_{1/2} = \ell n(2) / (k)(\text{OH}^-) T$$

with $(\text{OH}^-) = 1.5 \times 10^6$

	<u>k</u>	<u>$t_{1/2} = (\text{seconds})$</u>
Methanol	0.15×10^{-12}	30.8×10^5
Ethanol	1×10^{-12}	4.6×10^5
MTBE	0.60×10^{-12}	7.7×10^5

The order is in increasing persistence ethanol, MTBE, and methanol.

2.7.23 Yes. Bases are first entries.

$$\frac{4800 \text{ g mol CCl}_4}{10^9 \text{ g mol air}} \left| \frac{10^3 \text{ g mol air}}{\text{kg mol air}} \right| \left| \frac{\text{kg mol air}}{22.8 \text{ m}^3} \right| \left| \frac{154 \text{ g CCl}_4}{\text{g mol CCl}_4} \right| \left| \frac{10^3 \text{ mg CCl}_4}{\text{g CCl}_4} \right| =$$

32.4 mg CCl₄/m³ which exceeds the NIOSH standards

2.7.24

a.
$$\frac{25,600 \text{ ton P}}{\text{yr}} \left| \frac{2.6 \text{ yr}}{1} \right| \left| \frac{1}{1.2 \times 10^{14} \text{ gal}} \right| \left| \frac{1 \text{ gal}}{3.785 \text{ L}} \right| \left| \frac{2000 \text{ lb}}{1 \text{ ton}} \right| \left| \frac{454 \text{ g}}{1 \text{ lb}} \right| \left| \frac{10^6 \mu \text{ g}}{1 \text{ g}} \right|$$

$$= 133.1 \mu\text{g/L}$$

b.
$$\frac{19,090 \text{ lb(P)}_{\text{municipal}}}{30,100 \text{ lb(P)}_{\text{total}}} = \boxed{63.4\%}$$

c.
$$\frac{19,090 \text{ lb(P)}_{\text{municipal}}}{30,100 \text{ lb(P)}_{\text{total}}} \left| \frac{0.70 \text{ lb(P)}_{\text{det.}}}{1 \text{ lb(P)}_{\text{municipal}}} \right| \left| \frac{100 \text{ lb(P)}_{\text{total}}}{30,100 \text{ lb(P)}_{\text{total}}} \right| = \boxed{44.4\%}$$

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For d. and e. assume that (P)outflow remains unchanged.

d.
$$\text{P retained/yr} = 2,240 + 6,740 + 0.7 \times 19,090 - 4,500 = 17,843 \text{ ton/yr.}$$

P conc. in ppb =

$$\frac{17,843 \text{ ton}}{\text{yr}} \left| \frac{2.6 \text{ yr}}{1} \right| \left| \frac{1}{1.2 \times 10^{14} \text{ gal}} \right| \left| \frac{2000 \text{ lb}}{\text{ton}} \right| \left| \frac{1 \text{ g / cm}^3}{8.345 \text{ lb / gal}} \right| \left| \frac{10^9 \text{ g}}{1 \text{ billion g}} \right| = 92.6 \text{ ppb}$$

This is greater than 10 ppb. Eutrophication will not be reduced.

e.
$$\text{P retained/yr} = 2,240 + 6,740 + 0.3 \times 19,090 - 4,500 = 10,207 \frac{\text{ton}}{\text{yr}}$$

P conc. in ppb =

$$\frac{10,207 \text{ ton}}{\text{yr}} \left| \frac{2.6 \text{ yr}}{1} \right| \left| \frac{1}{1.2 \times 10^{14} \text{ gal}} \right| \left| \frac{2000 \text{ lb}}{\text{ton}} \right| \left| \frac{1 \text{ g / cc}}{8.345 \text{ lb / gal}} \right| \left| \frac{10^9 \text{ g}}{1 \text{ billion g}} \right| = 53.2 \text{ ppb}$$

This will not help.

2.7.25Basis: 10^6 g mol gas

$$\frac{350 \text{ g mol H}_2\text{S}}{10^6 \text{ g mol gas}} \left| \frac{1 \text{ g mol gas}}{1 \text{ g mol CO}_2} \right| \frac{34 \text{ g H}_2\text{S}}{1 \text{ g mol H}_2\text{O}} \left| \frac{1 \text{ g mol CO}_2}{44 \text{ g CO}_2} \right|$$

$$= \frac{270}{10^6} \frac{\text{g H}_2\text{S}}{\text{g CO}_2} = \frac{270}{10^6} \frac{\text{g H}_2\text{S}}{\text{g total liquid}}$$

$$\text{mass fraction H}_2\text{S} = \boxed{2.70 \times 10^{-4}}$$

2.7.26

(a) $\frac{1 \text{ mol O}_2}{100 \text{ mol gas}} \Rightarrow \frac{10^4 \text{ mol O}_2}{10^6 \text{ mol gas}}$ or 10^4 ppm

(b) Basis: 100 mol gas

answer

<u>Comp.</u>	<u>% = mol</u>	<u>mol fr.</u>	<u>or mol %</u>
SO ₃	55	0.932	93.2
SO ₂	3	0.051	5.1
O ₂	<u>1</u>	<u>0.017</u>	<u>1.7</u>
Total	59	1.000	100.0

2.7.27MW CaCO₃: 100.06

Ca 40.05

Mg 24.3

C 12.01

O 16.00

$$\frac{100.06 \text{ g CaCO}_3}{\text{g mol Ca CO}_3} \left| \frac{1 \text{ g mol CaCO}_3}{1 \text{ g mol Ca}} \right| \frac{1 \text{ g mol Ca}}{40.05 \text{ g Ca}} = 2.50 \frac{\text{g CaCO}_3}{\text{g Ca}}$$

$$\text{Similarly } \frac{\text{g CaCO}_3}{\text{g Mg}} = 4.118 \frac{\text{g CaCO}_3}{\text{g Mg}}$$

$$\text{Total alkalinity} = 2.50 (56.4) + 4.118 (8.8) = \boxed{177 \frac{\text{mg CaCO}_3}{\text{L}}}$$

2.7.28 No. 1 molecule in 10^{23} or more is not 13-20 ppb

2.7.29 On a mol basis, the carbon dioxide concentration in air is about 350 parts per million (ppm), while that of oxygen is about 209,500 ppm. If the atmospheric concentration of carbon dioxide is increasing at about 1% per year (i.e., from 350 ppm this year to 353.5 ppm next year), and not to 1%, the 3.5-ppm change in dioxide concentration causes the oxygen concentration to fall from 209,500 to about 209,497 ppm, which is less than a 0.002% decrease. So, there is no need to worry about an oxygen deficit at present.

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