SOLUTIONS - 12 FORMULAE

1 mol of a material has 6.02×10^{23} units $= N_A$
(atoms or molecules)

Molar mass (weight) = atomic mass # in grams

Properties of Thermodynamic system:

$\underline{V}$ - Volume

$\underline{P}$ - Pressure $P = F/A$ (force per unit area on the walls)

away from Earth P is isotropic and uniform. Near Earth

$$\Delta P = -\rho g \Delta y$$

ρ = density of fluid.

For liquids $P(h) = P_A + \rho g h$

where h is the depth.

θ - Temperature is the property which is needed to specify thermal $\equiv$m.

Two systems can be in $\equiv$m only if

$$\theta_1 = \theta_2$$

Effects of temperature:

In solids and liquids we talk of thermal expansion:

Solid: length $l = l_0[1 + \alpha(\theta - \theta_0)]$

Area $A = A_0[1 + 2\alpha(\theta - \theta_0)]$

vol. $V = V_0[1 + 3\alpha(\theta - \theta_0)]$

In liquids:

vol. $V = V_i[1 + \beta(\theta - \theta_0)]$, $\Delta V = V_i \beta \Delta\theta$

Scales of Temperature - from Melting point and Boiling pt. of water at atmospheric Pressure

	Celsius(C)	Fahrenheit (F)
M.P	0	32
BP	100	212

Relationship $\frac{F-32}{9} = \frac{C}{5}$

GASES. IDEAL GAS LAW

$$PV = Nk_BT = nRT$$

N = # of atoms/molecules

k_B = Boltzmann's Const = 1.38×10^{-23} J/K

T = Absolute or Kelvin Temp. [M.P. 273K
B.P. 373K]

n = # of moles

$R = N_A k_B \simeq 8.3$ J/mol/K.

Kinetic Theory

$$P = \frac{1}{3} m \frac{N}{V} \overline{c^2}$$

so $$\frac{1}{2} m\overline{v^2} = \frac{3}{2} k_B T$$

Kinetic Energy per particle

$\overline{v^2}$ = mean square speed of gas particles

Heat: DQ : Energy Exchanged between systems when they are at different temperatures — Higher Temperature system loses energy and lower temperature gains it

$$DQ_1 + DQ_2 = 0 \quad \text{[Conservation Law]}$$

Change of temperature

$$DQ = Mc\,\Delta\theta \qquad c = \text{sp. ht.}$$

Change of phase

$$DQ = ML \qquad L = \text{Latent Ht.}$$

Calorimetry $\quad \sum M_i c_i \Delta\theta_i + \sum M_j L_j = 0$

(CONSERVATION LAW)

TRANSPORT OF HEAT

1. CONDUCTION $\quad \dfrac{DQ}{\Delta t} = -kA\dfrac{\Delta T}{\Delta x}$

Layer by layer

2. CONVECTION : THERMAL STIRRING

NO EQN

3. RADIATION CONTINUOUS EMISSION FROM SURFACE

$$\frac{DQ}{\Delta t} = \underbrace{A}_{\text{surface area}}\,\underbrace{e}_{\text{emissivity}}\,\sigma\left(T_1^4 - T_2^4\right)$$

Stefan-Boltzmann Const $\sigma = 5.7\times10^{-8}\ W/m^2 \cdot K^4$

Solutions – Ch 12

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1.0 mol. of Oxygen gas $\equiv 6.02 \times 10^{23}$ molecules of Oxygen
$\equiv 2 \times 6.02 \times 10^{23}$ atoms of Oxygen
(since 1 molecule of Oxygen gas, O_2, contains 2 atoms of oxygen)

Since 1 molecule of H_2O contains only 1 atom of Oxygen, $2 \times 6.02 \times 10^{23}$ atoms of oxygen will be contained in $2 \times 6.02 \times 10^{23}$ molecules of water.

And,
$2 \times 6.02 \times 10^{23}$ molecules of water $\equiv$ 2.0 mol. of water
$\equiv 2 \times (1 \times 2 + 16 \times 1)$ g of water
$= 36$ g of water

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$$\text{Change in volume } (\Delta V) = \beta V_i \Delta T$$
$$= (1100 \times 10^{-6})(0.865)(35 - 12)$$
$$= 0.022 \text{ L}$$

$$\therefore \text{New volume} = V_i + \Delta V$$
$$= 0.865 + 0.022$$
$$= 0.887 \text{ L}$$

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Since the diameter is provided, we can assume the eardrum to be circular.

$$\text{Area of the ear drum} = \pi R^2$$
$$= \pi \left(\frac{8.4 \times 10^{-3}}{2}\right)^2$$
$$= 5.54 \times 10^{-5} \text{ m}^2$$

Outward force on the eardrum
$$= pA$$
$$= (45 \times 10^3)(5.54 \times 10^{-5})$$
$$= 2.49 \text{ N}$$

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Volume of O_2 inhaled $= 20\%$ of $5.0 \text{L} = \frac{20}{100} \times 5 = 1.0 \text{L} = 10^{-3} \text{m}^3$

Given data: p = pressure at sea level
$= 1.013 \times 10^5$ Pa

$T = 37°C = 310$ K

Using $R = 8.31 \text{ J mol}^{-1} \text{K}^{-1}$ in the ideal gas equation $pV = nRT$, we have

$$n = \frac{pV}{RT} = \frac{(1.013 \times 10^5)(10^{-3})}{(8.31)(310)} = 0.04 \text{ mol of } O_2$$

19 $(1\times 2 + 16\times 1 =)$ 18 g of water makes up 1.0 mol of water.

$\therefore$ 10g of water $\equiv \frac{10}{18}$ or 0.55 mol. of water

Now, 0.55 mol. of water becomes 0.55 mol. of steam at 100°C when heated at $T = 100\,°C$ or 373 K

and $p =$ atmospheric pressure $= 1.013\times 10^5$ Pa

ASSUME THAT STEAM IS AN IDEAL GAS.

$\therefore$ Using the ideal gas equation, $V = \frac{nRT}{P}$

$$= \frac{(0.55)(8.31)(373)}{(1.013\times 10^5)}$$

$$= 0.017\,m^3$$

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a) Since the expansion is isothermal, the final temperature is also 20°C or 293 K.

So, using the ideal gas equation,

$$P_f = \frac{nRT_f}{V_f}$$ (subscript 'f' denotes quantities pertaining to the final state)

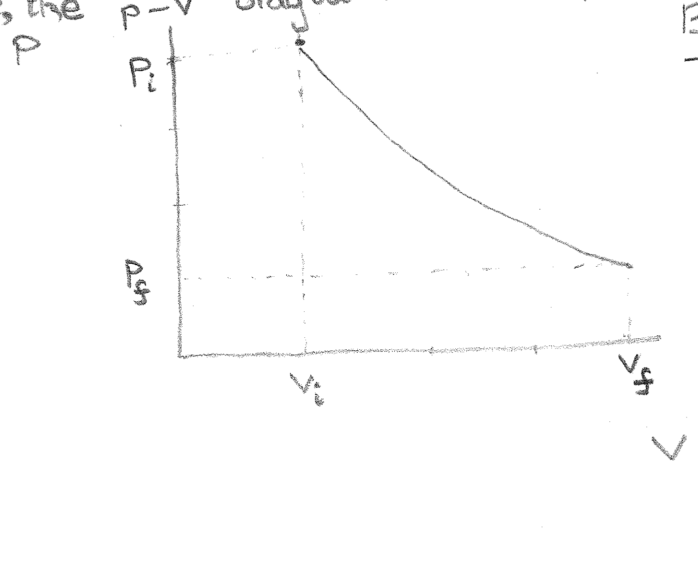
$$= \frac{(0.10)(8.31)(293)}{(200\times 10^{-6})}$$

$$= 1.22\times 10^6 \text{ Pa}$$

b) Since the final volume is 4 times the initial volume, using the equation $\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$ (equation valid for gases in a sealed container)

$$P_i = 4P_f = 4.88\times 10^6 \text{ Pa}$$

Hence, the p–V diagram for the process is:



BOYLE'S LAW TELLS US THAT IF T is CONST.

$P \propto \frac{1}{V}$

27)

a) Since the pressure remains the same all throughout the process, the diagram represents an isobaric process.

At const. pressure
V is Proportional to T!

b) Using the equation $\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$,

where $V_f = V_i/3$ and $P_f = P_i$,

we get $T_f = T_i/3 = (900 + 273)/3$
$= 1173/3$
$= 391\ K$
$= 118°C$

c) No. of moles $= \frac{PV}{RT} = \frac{(3 \times 1.013 \times 10^5)(100 \times 10^{-6})}{(8.314)(391)} = 9.4 \times 10^{-3}$ mol.

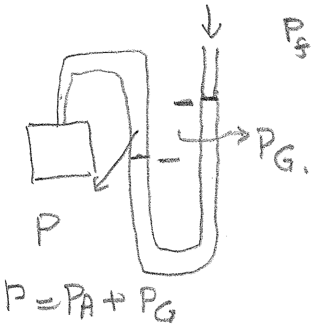
29) $T_i = 0\ °C = 273 K$

$T_f = ?$

Since the container is sealed and is also rigid (meaning that it does not expand or contract), $V_i = V_f$.

$P_i = 55.9\ kPa + 101.3\ kPa = 157.2\ kPa$ (gauge pressure → absolute pressure)

$P_f = 65.1\ kPa + 101.3\ kPa = 166.4\ kPa$



$\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$ (again, note that this equation is valid if the container is sealed)

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

$= \frac{166.4}{157.2} \times 273 = 289\ K = 16°C$

34) To evaporate $25 mg = 2.5 \times 10^{-5}$ Kg of water, the energy required would be $mL_v = (2.5 \times 10^{-5})(24 \times 10^5) = 60\ J$

So, for every breathe exhaled, an energy of 60 J is drawn from the body.

Hence, at the rate of 12 breaths/min., an energy of $60 \times 12 = 720 J$ will be lost from the body. per minute.

38) Let the initial temperature of the pan be T_i.

Assuming that no heat is lost while the Aluminium pan is moved to the sink, we have

Heat lost by Al pan = heat gained by water

$$\Rightarrow \underbrace{(0.75)(900)}_{\text{specific heat of Al}}(T_i - 24) = (1.00)\underbrace{(4190)}_{\text{Specific heat of water}}(24 - 20)$$

See table on Pg 390 of book

[Formula used : Heat lost/gained = $mc\Delta T$]

Solving, $T_i = 270°C$

45) Work done in the cycle

= Area enclosed by the p-V curve (A triangle in this case)

= $\frac{1}{2} \times$ Base length $\times$ height (of the triangle shown in figure)

$$= \frac{1}{2} \times \left[(600 - 200) \times 10^{-6}\right] \times \left[(3-1) \times \underbrace{1.013 \times 10^5}\right]$$

= 40.52 J

To convert cm^3 to m^3

To convert atm to Pa

48) Rate of heat loss due to conduction $= \left(\frac{kA}{L}\right)\Delta T = 800W$

Here, k = Thermal conductivity of copper = 400 W/mK

$A = \pi r^2 = \pi\left(\frac{0.24}{2}\right)^2 = 0.045\ m^2$

$L = 3.0\ mm = 3.0 \times 10^{-3}\ m$

This gives, $\Delta T = 0.13\ °C$

Since the inside of the kettle is at 100°C (the temperature of boiling water), the bottom of the kettle is at 100 + 0.13 = 100.13 °C.