XII

UNIT 15

UNIT-15 SCALE OF TEMPERATURE

1 On a day when the temperature reaches 50 ^{0}F, what is the temperature in degrees Celsius and in kelvins? [10 ^{0}C , 283 K]

2 (a) On a fine spring day, you notice that the temperature is 75°F. What is the corresponding temperature on the Celsius scale? (b) If the temperature on a brisk winter morning is -2.0 °C, what is the corresponding Fahrenheit temperature?

[24 °C , 28 °F]

3 Normal body temperature is 98.6°F. What is this on the Celsius scale?

[37.0°C]

4 The temperature gradient between the skin and the air is regulated by cutaneous (skin) blood flow. If the cutaneous blood vessels are constricted, the skin temperature and the temperature of the environment will be about the same. When the vessels are dilated, more blood is brought to the surface. Suppose the skin warms from 72.0°F to 84.0°F during dilation. (a) Convert these temperatures to Celsius and find the difference. (b) Convert the temperatures to Kelvin, again finding the difference.

[(a) 22°C, 29°C, ΔT = 7°C , (b) 295 K , 302 K , ΔT = 7 K]

5 The temperature at the surface of the Sun is about 6000 K. Convert this temperature to the (a) Celsius and (b) Fahrenheit scales. [5727 °C , 10340 ^{0}F]

UNIT-15 BOY'S LAW CHARLES'S LAW GENERAL EQUATIONS

1 Calculate the volume occupied by a gram-mole of a gas at 10 °C and a pressure of one atmosphere. [Given: R = 8.313 J/mole-k, One atmosphere = 1.01×10^5 N/m^2]

[0.023 m^3]

2 One gram mole of a gas occupies a volume of 24.93 m^3, at a pressure of 500 N/m^2, find the temperature of the gas in centigrade. Given R = 8.313 J/mole-K. [1226.5°C]

3 A tank containing 0.1 m^3 of nitrogen at room temperature and at a pressure of 8×10^6 N/m^2 is connected through a valve to an empty tank of volume 0.4 m^3. The valve is opened, and the nitrogen is allowed to expand. After the system returns to room temperature, what is the pressure of the tank? [1.6 x 10^6 N/m^2]

4 How many moles of air are in an inflated basketball? Assume the pressure in the ball is 159 kPa, the temperature is 293 K, and the diameter of the ball is 23.0 cm.

[0.416 mol]

ASSIGNMENT

5 Find the masses of (a) an atom of iron, F_e, and (b) a molecule of nitrogen, N_2

[atomic mass of iron = 55.85 g/mol, atomic mass of Nitrogen = 14.01 g/mol]

[Ans 9.274 x 10^{-23} g/atom = 9.274 x 10^{-26} kg/atom]

[Ans 653 x 10^{-23} g / molecule = 4.653 x 10^{-26} kg / molecule]

6 A scientist stores 22 g of a gas in a tank at 1200 atmospheres. Overnight, the tank develops a slight leakage, and the pressure drops to 950 atmospheres. Calculate the mass of the gas that escaped [m_2 = 17.42 g, escaped gas from tank = 22- 17.42 = 4.58 g]

7 An air-storage tank whose volume is 110 liters contains 2 kg of air at a pressure of 15 atmospheres. How much air would have to be forced into the tank to increase the pressure to 18 atmospheres, assuming no change in temperature?

[m_2 = 2.4 kg , mass of air forced into tank = 2.4 – 2.0 = 0.4 kg]

8 An auditorium has dimensions 10.0 m x 20.0 m x 20.0 m. How many molecules of air fill the auditorium at 20.0 ^{0}C and a pressure of 101 kPa?

[n = 1.658 x 10^5 moles, number of molecules = n x N_A = 9.98 x 10^{28}]

9 Estimate the number of moles of air molecules there are in a room 4 m by 6m by 3m at the standard pressure and room temperature (20 ^{0}C).

[2.98 x 10^3 moles]

10 A weather balloon is being prepared for launch. Initially, it holds 6.86 m3 of hydrogen at 277 K. As pre-launch preparations continue in the morning sun, the temperature of the hydrogen rises to 288 K. What is the volume of the hydrogen at this new temperature? (The skin of the balloon is loose at launch, and has negligible effect on the pressure of the gas it contains.)

[7.13 m^3]

UNIT-15 PRESSURE OF THE GAS AND KINETIC THEORY OF GASES

1 Find the average kinetic energy of oxygen molecules in the air. Assume the air is at a temperature of 23 °C. [6.13 x 10^{-21} J]

2 Calculate the root-mean-square speed of a hydrogen molecule at 800 K.

(Mass of proton = 1.67 x 10^{-27} kg & k=1.38x10^{-23}) [Ans 3148.9 m/s]

3 (a) Determine the average value of the particles of an ideal gas at 0°C and at 50°C.

(b) What is the kinetic energy per mole of an ideal gas at these temperatures?

(a) (i) T = 0°C = 273 k, <k.e>= ?

$\langle k.e.\rangle = \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 273 = 56.5 \times 10^{-23}$

$\boxed{\langle k.e\rangle = 5.65 \times 10^{-21}\ J}$ ______________________(1)

(ii) T = 50° C =273 + 50 = 323K, <k.e.> =?

$\langle k.e.\rangle = \frac{3}{2}\ kT\ \frac{3}{2} \times 1.38 \times 10^{-23} \times 323 = \boxed{6.69 \times 10^{-21}\ J}$ ______________________(2)

(b) K.e. per mole = E = ?

(i) $E = N_A x \langle k.e.\rangle = 6.02 \times 10^{23} \times 5.65 \times 10^{-21} = 34.013 \times 10^{2}$

$\boxed{E = 34013\ J/\ mole}$ ______________________(1)

(ii) $E = NA \times \langle k.e.\rangle = 6.02 \times 10^{23} = 6.69 \times 10^{-21} = \boxed{4027.3\ J/mole}$ ______________________(2)

4 Find the V_{rms} speed of N_2 and O_2 at 293 K.

Solution

1. To find the rms speed of N_2, substitute $M = 0.0280$ kg/mol in $v_{rms} = \sqrt{3RT/M}$: $$v_{rms} = \sqrt{\frac{3[8.31\ J/(mol \cdot K)](293\ K)}{0.0280\ kg/mol}} = 511\ m/s$$
2. To find the rms speed of O_2, substitute $M = 0.0320$ kg/mol in $v_{rms} = \sqrt{3RT/M}$: $$v_{rms} = \sqrt{\frac{3[8.31\ J/(mol \cdot K)](293\ K)}{0.0320\ kg/mol}} = 478\ m/s$$

5 A spray can containing a propellant gas at twice atmospheric pressure (202 kPa) and having a volume of 125.00 cm^3 is at 22 ^{0}C. It is then tossed into an open fire. (Warning: Do not do this experiment; it is very dangerous.) When the temperature of the gas in the can reaches 195 ^{0}C, what is the pressure inside the can? Assume any change in the volume of the can is negligible [320 kPa]

6 Determine the volume of 1.00 mol of any gas, assuming it behaves like an ideal gas, at STP. [Hint PV = nRT Ans 22.4 x 10^{-3} m^3]

7 Air at 27°C and 1.0 atmospheric pressure is suddenly compressed to one twentieth of its original volume, and a pressure of 30 atmospheres. What is the temperature of the gas? [450 k or 177 °C]

8 **Calculate the V_{rms} of hydrogen molecules at 0°C and 1.00 atm. Pressure, assuming hydrogen to be an ideal gas having density $\rho = 8.99 \times 10^{-2}$ kg m^{-3}**

[hint $V_{rms} = \sqrt{\frac{3p}{\rho}}$ Ans = 1836 ms^{-1}]

9 **Calculate the average speed of a proton at the temperature of a hydrogen bomb, which is about 107 K. Take the mass of a proton as 1.67×10^{-27} kg.**
[5×10^5 ms^{-1}

10 **A helium party balloon, assumed to be a perfect sphere, has a radius of 18.0 cm. At room temperature (20°C), its internal pressure is 1.05 atm. Find the number of moles of helium in the balloon and the mass of helium needed to inflate the balloon to these values.**

SOLUTION We get the volume V from the formula for a sphere:

$$V = \tfrac{4}{3}\pi r^3 = \tfrac{4}{3}\pi\,(0.180\text{ m})^3 = 0.0244\text{ m}^3.$$

The pressure is given as $1.05\text{ atm} = 1.064 \times 10^5\text{ N/m}^2$. The temperature must be expressed in kelvins, so we change 20°C to $(20 + 273)\text{K} = 293\text{ K}$. Finally, we use the value $R = 8.314\text{ J/(mol}\cdot\text{K)}$ because we are using SI units. Thus

$$n = \frac{PV}{RT} = \frac{(1.064 \times 10^5\text{ N/m}^2)(0.0244\text{ m}^3)}{(8.314\text{ J/mol}\cdot\text{K})(293\text{ K})} = 1.066\text{ mol.}$$

The mass of helium (atomic mass $= 4.00\text{ g/mol}$ as given in the Periodic Table or Appendix B) can be obtained from

$$\text{mass} = n \times \text{molecular mass} = (1.066\text{ mol})(4.00\text{ g/mol}) = 4.26\text{ g}$$

or 4.26×10^{-3} kg.