**Gas laws**

* Matter is made up of small particle in accordance to Kinetic Theory of matter:

Naturally, there are basically **three** states of matter: **Solid, Liquid** and **gas:**

(i)A solid is made up of particles which are very closely packed with a definite/fixed shape and fixed/definite volume /occupies definite space. It has a very high density.

(ii) A liquid is made up of particles which have some degree of freedom. It thus has no definite/fixed shape. It takes the shape of the container it is put. A liquid has fixed/definite volume/occupies definite space.

(iii)A gas is made up of particles free from each other. It thus has no definite /fixed shape. It takes the shape of the container it is put. It has no fixed/definite volume/occupies every space in a container.

* Gases are affected by **physical conditions**. There are **two** physical conditions:

(i)**Temperature**

(ii)**Pressure**

* The SI unit of temperature is **Kelvin**(**K**).

**Degrees** Celsius/Centigrade(**oC**) are also used.

* The two units can be interconverted from the relationship:
* **oC + 273= K**
* **K -273 = oC**

Practice examples

1. Convert the following into Kelvin.

(i) O **oC**

**oC + 273 = K substituting :** O oC + 273 = **273 K**

(ii) -273 **oC**

**oC + 273 = K substituting :** -273oC + 273 = **0 K**

2. Convert the following into degrees Celsius/Centigrade(oC).

(i) 10 K

**K -273 = oC substituting:** 10 – 273 = **-263 oC**

(ii) (i) 1 K

**K -273 = oC substituting:** 1 – 273 =  **-272 oC**

(iii) 110 K

**K -273 = oC substituting: 110 – 273 = -163 oC**

NB/ The **room** temperature is assumed to be **298K** = **25oC**

* The SI unit of pressure is Pascal (**Pa**).
* Millimeters ‘of mercury (**mmHg**) and **atmospheres** are also commonly used.
* One atmosphere= 760 mmHg
* Molecules of gases are always in continuous random motion at high speed. This motion is affected by the physical conditions of temperature and pressure.
* Physical conditions change the volume occupied by gases in a **closed** system.
* The effect of physical conditions of temperature and pressure was investigated and expressed in both Boyles and Charles laws.

**Boyle’s law**

* Boyle’s law states that “the volume of a fixed mass of a gas is inversely proportional to pressure at constant/fixed temperature”

**Mathematically:**

Volume α 1 **(Fixed /constant Temperature)**

Pressure

V α 1 **(Fixed /constant T)** i.e. **PV = Constant**(k)

P

* From Boyle’s law, an **increase** in pressure of a gas causes a **decrease** in volume. i.e **doubling** the pressure cause the volume to be **halved**.
* Graphically therefore a plot of volume (**V**) **against** pressure (**P**) produces a **curve**.

V

P

* Graphically a plot of volume(**V**) **against** inverse/reciprocal of pressure (**1/p**) produces a **straight line**

**V**

**1/P**

* For **two** gases then P1 **V1 = P2 V2**

P1 = Pressure of gas 1

V1 = Volume of gas 1

P2 = Pressure of gas 2

V2 = Volume of gas 2

Practice examples:

**1. A fixed mass of gas at 102300Pa pressure has a volume of 25cm3.Calculate its volume if the pressure is doubled.**

Working

P1 V1 = P2 V2 Substituting :102300 x 25 = (102300 x **2**) x V2

V2 = 102300 x 25 = **12.5cm3**

(102300 x 2)

**2. Calculate the pressure which must be applied to a fixed mass of 100cm3 of Oxygen for its volume to triple at 100000Nm-2.**

P1 V1 = P2 V2 Substituting :100000 x 100 = P2 x (100 x **3**)

V2 = 100000 x 100 = **33333.3333 Nm-2**

(100 x 3)

**3.A 60cm3 weather ballon full of Hydrogen at atmospheric pressure of 101325Pa was released into the atmosphere. Will the ballon reach stratosphere where the pressure is 90000Pa?**

P1 V1 = P2 V2 Substituting :101325 x 60 = 90000 x V2

V2 = 101325 x 60 = **67.55 cm3**

90000

The new volume at 67.55 cm3 **exceed** ballon capacity of 60.00 cm3.It will **burst** before reaching destination.

**Charles law**

* Charles law states that “the volume of a fixed mass of a gas is directly proportional to the absolute temperature at constant/fixed pressure ”

Mathematically:

Volume α Temperature **(Fixed /constant pressure)**

V α T  **(Fixed /constant P)** i.e. **V = Constant**(k)

T

* From Charles law, an **increase** in temperature of a gas causes an **increase** in volume. i.e **doubling** the temperature cause the volume to be **doubled**.
* The volume of a gas continues decreasing with decrease in temperature until at -**273oC /0 K** the volume is **zero**. i.e. there is no gas.
* This temperature is called **absolute zero.** It is the **lowest** temperature at which a gas **can** exist.
* Graphically therefore a plot of volume(**V**) **against** Temperature(**T**) in:

1. oC produces a **straight line** that is **extrapolated** to the absolute zero of -273**oC** .

V

**-273oC** **0oC**

T(**oC**)

(**ii**)Kelvin/K produces a **straight line** from absolute zero of **O Kelvin**

**V**

**0 T(Kelvin)**

For **two** gases then **V1  = V2**

**T1  T2**

T1 = Temperature **in Kelvin** of gas 1

V1 = Volume of gas 1

T2 = Temperature **in Kelvin** of gas 2

V2 = Volume of gas 2

Practice examples:

**1. 500cm3 of carbon(IV)oxide at 0oC was transfered into a cylinder at -4oC. If the capacity of the cylinder is 450 cm3,explain what happened.**

V1  = V2 substituting 500 = V2

T1  T2 (0 +273) (-4 +273)

= 500 x (-4 x 273) = **492.674cm3**

(0 + 273)

The capacity of cylinder (500cm3) is **less** than new volume (492.674cm3).

**7.326cm3**(500-492.674cm3) of carbon(IV)oxide gas did not fit into the cylinder.

**2. A mechanic was filling a deflated tyre with air in his closed garage using a hand pump. The capacity of the tyre was 40,000cm3 at room temperature. He rolled the tyre into the car outside. The temperature outside was 30oC.Explain what happens.**

V1  = V2 substituting 40000 = V2

T1  T2 (**25** +273) (**30** +273)

= 40000 x (30 x 273) = **40671.1409cm3**

(25 + 273)

The capacity of a tyre (40000cm3) is **less** than new volume(40671.1409cm3).

The tyre thus bursts.

**3. A hydrogen gas balloon with 80cm3 was released from a research station at room temperature. If the temperature of the highest point it rose is -30oC , explain what happened.**

V1  = V2 substituting 80 = V2

T1  T2 (**25** +273) (-**30** +273)

= 80 x (-30 x 273) = **65.2349cm3**

(25 + 273)

The capacity of balloon (80cm3) is **more** than new volume (65.2349cm3).

The balloon thus remained intact.

**Diffusion of gases**

* The continuous random motion of gases differs from gas to the other.
* The movement of molecules (of a gas) from region of high concentration to a region of low concentration is called **diffusion.**
* The rate of diffusion of a gas depends on its density. i.e. **The higher the rate of diffusion, the less dense the gas**.
* The density of a gas depends on its molar mass/relative molecular mass. i.e. The higher the density the higher the molar mass/relative atomic mass and thus the lower the rate of diffusion.

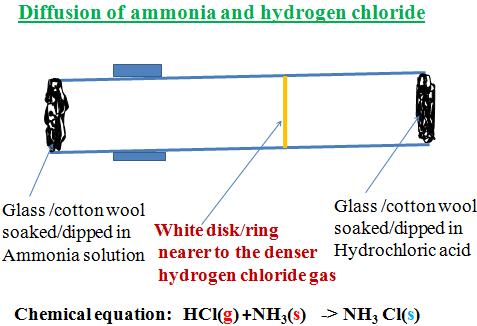
Examples

1. Carbon (IV) oxide (CO2) has a molar mass of 44g.Nitrogen (N2) has a molar mass of 28g. (N2) is thus lighter/less dense than Carbon (IV) oxide(CO2). N2 diffuses faster than CO2.

2. Ammonia (NH3) has a molar mass of 17g.Nitrogen (N2) has a molar mass of 28g. (N2) is thus about **twice** lighter/less dense than Ammonia (NH3). Ammonia (NH3)diffuses twice faster than N2.

3. Ammonia (NH3) has a molar mass of 17g.Hydrogen chloride gas has a molar mass of 36.5g.Both gases on contact react to form **white fumes** of ammonium chloride.

* When a glass/cotton wool dipped in ammonia and another glass/cotton wool dipped in hydrochloric acid are placed at opposite ends of a glass tube, both gases diffuse towards each other. A white disk appears near to glass/cotton wool dipped in hydrochloric acid. This is because hydrogen chloride is heavier/denser than Ammonia and thus its rate of diffusion is lower.



* The rate of diffusion of a gas is in accordance to **Graham’s law of diffusion**.
* Grahams law states that: “the rate of diffusion of a gas is inversely proportional to the square root of its density, at the same/constant/fixed temperature and pressure”

**Mathematically**

**R α 1**  and since density is proportional to mass then **R α 1**

**√ p √ m**

For two gases then:

**R1  = R2** where: R**1** and R**2** is the **rate** of diffusion of **1**st and **2**nd gas.

**√M2 √M1** M**1** and M**2** is the **molar mass** of **1**st and **2**nd gas.

Since rate is inverse of time. i.e. the higher the rate the less the time:

For two gases then:

T**1**= T2 where: T**1** and T**2** is the **time taken** for **1**st and **2**nd gas to diffuse.

**√**M1 **√**M2  M**1** and M**2** is the **molar mass** of **1**st and **2**nd gas.

**Practice examples**:

**1. It takes 30 seconds for 100cm3 of carbon (IV) oxide to diffuse across a porous plate. How long will it take 150cm3 of nitrogen (IV) oxide to diffuse across the same plate under the same conditions of temperature and pressure? (C=12.0, N=14.0=16.0)**

Molar mass CO2=44.0 Molar mass NO2=46.0

Method 1

100cm3 CO2  takes 30seconds

150cm3 takes 150 x30 = 45seconds

100

T CO2 = √ molar mass CO2 = 45seconds = √ 44.0

T NO2  √ molar mass NO2 T NO2 √ 46.0

T NO2  = 45seconds x √ 46.0 = **46.0114** seconds

√ 44.0

Method 2

100cm3 CO2  takes 30seconds

1cm3 takes 100 x1 = **3.3333cm3sec-1**

30

R CO2 = √ molar mass NO2 = 3.3333cm3sec-1 = √ 46.0

R NO2  √ molar mass CO2 R NO2 √ 44.0

R NO2  = 3.3333cm3sec-1 x √ 44.0 = **3.2601**cm3sec-1

√ 46.0

3.2601cm3 takes 1seconds

150cm3 take 150cm3 = **46.0109seconds**

3.2601cm3

**2. How long would 200cm3 of Hydrogen chloride take to diffuse through a porous plug if carbon (IV) oxide takes 200seconds to diffuse through?**

Molar mass CO2 = 44g Molar mass HCl = 36.5g

T CO2 = √ molar mass CO2 => 200 seconds = √ 44.0

T HCl √ molar mass HClT HCl√ 36.5

T HCl = 200seconds x √ 36.5 = **182.1588** seconds

√ 44.0

**3. Oxygen gas takes 250 seconds to diffuse through a porous diaphragm. Calculate the molar mass of gas Z which takes 227 second to diffuse.**

Molar mass O2 = 32g Molar mass Z = x g

T O2 = √ molar mass O2 = 250 seconds = √ 32.0

T Z √ molar mass Z 227seconds√ x

√ x = 227seconds x √ 32 = **26.3828** grams

250

**4. 25cm3 of carbon (II) oxide diffuses across a porous plate in 25seconds. How long will it take 75cm3 of Carbon (IV) oxide to diffuse across the same plate under the same conditions of temperature and pressure? (C=12.0,0=16.0)**

Molar mass CO2 = 44.0 Molar mass CO = 28.0

Method 1

25cm3 CO takes 25seconds

75cm3 takes 75 x25 = 75seconds

25

T CO2 = √ molar mass CO2 = T CO2seconds = √ 44.0

T CO √ molar mass CO75√ 28.0

T CO2 =75seconds x √ 44.0 = **94.0175** seconds

√ 28.0

Method 2

25cm3 CO2  takes 25seconds

1cm3 takes 25 x1 = **1.0cm3sec-1**

25

R CO2 = √ molar mass CO = x cm3sec-1 = √ 28.0

R CO √ molar mass CO2 1.0cm3sec-1√ 44.0

R CO2 = 1.0cm3sec-1 x √ 28.0 = **0.7977**cm3sec-1

√ 44.0

0.7977cm3 takes 1 seconds

75cm3 takes 75cm3 = **94.0203seconds**

0.7977cm3