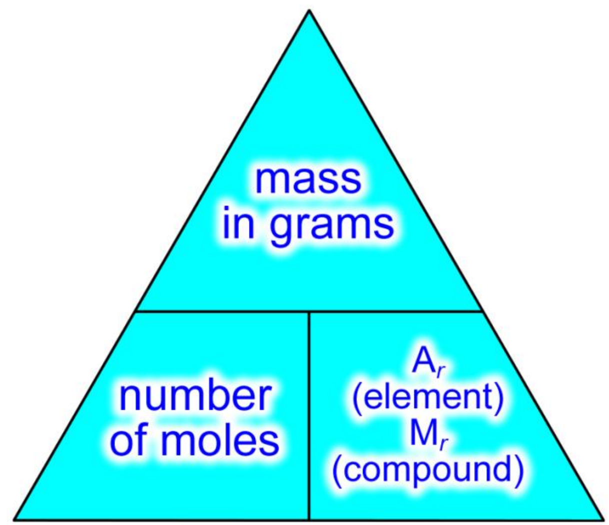
Mole Concept: Gases

NANYANG GIRLS' HIGH

Measuring the Amount of a Gas

I can easily measure the *mass* of a *solid* on a balance and convert this into a number of *moles*.



Measuring the Amount of a Gas

But many chemical reactions also involve *gases*! How do I measure the *mass* of a *gas* in the laboratory?

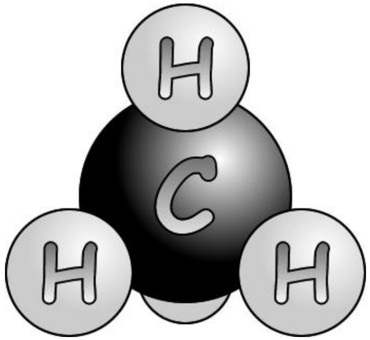
Measuring the Amount of a Gas

Unless there is *another property* of a *gas* that I can measure, instead of its mass.

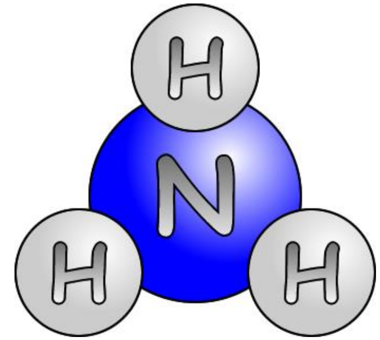
Measuring the Amount of a Gas

What about its *volume*? The *volume* of a *gas* can be easily measured using a gas syringe.

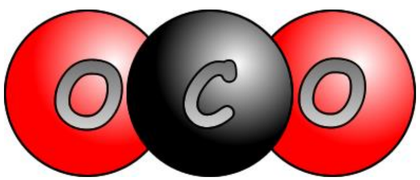
How many molecules of CH_4(g) in 1 mol?



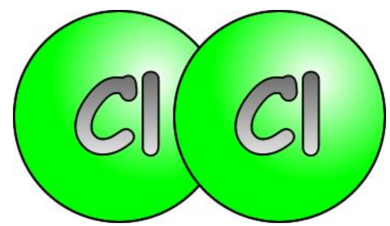
How many molecules of NH_3(g) in 1 mol?



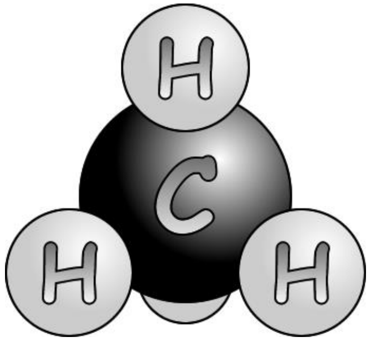
How many molecules of CO_2(g) in 1 mol?



How many molecules of Cl_2(g) in 1 mol?

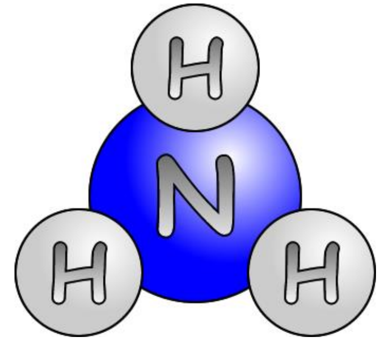


How many molecules of CH_4(g) in 1 mol?



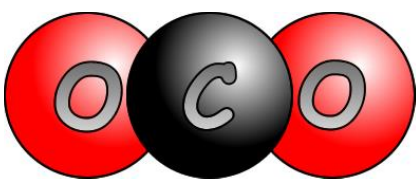
6×10^{23}

How many molecules of NH_3(g) in 1 mol?



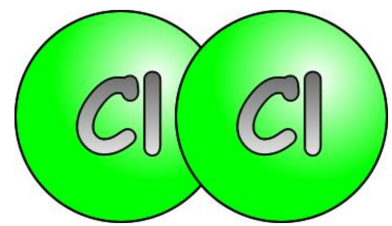
6×10^{23}

How many molecules of CO_2(g) in 1 mol?



6×10^{23}

How many molecules of Cl_2(g) in 1 mol?



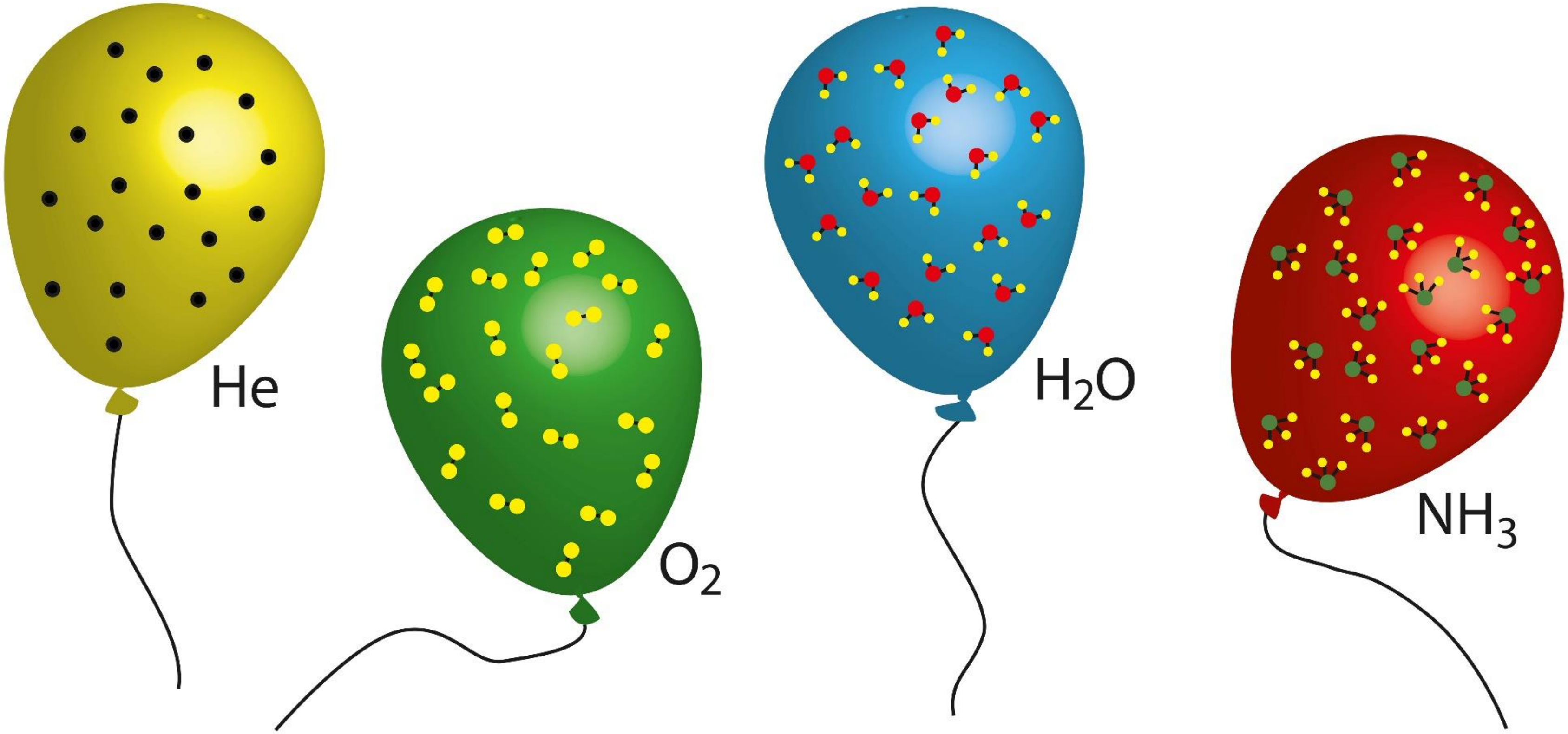
6×10^{23}

Measuring the Amount of a Gas

- 1 mol of $CH_4(g)$
- 1 mol of $NH_3(g)$
- 1 mol of $CO_2(g)$
- 1 mol of $Cl_2(g)$

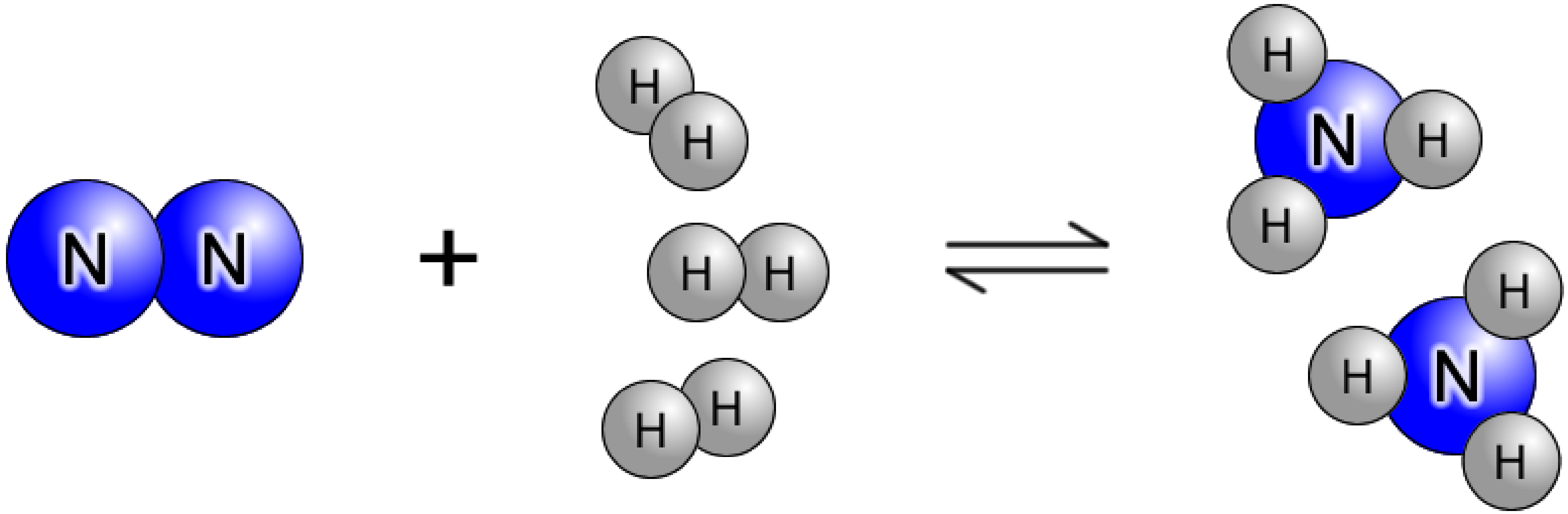
…all contain exactly the same number of molecules, 6×10^{23}.

Measuring the Amount of a Gas

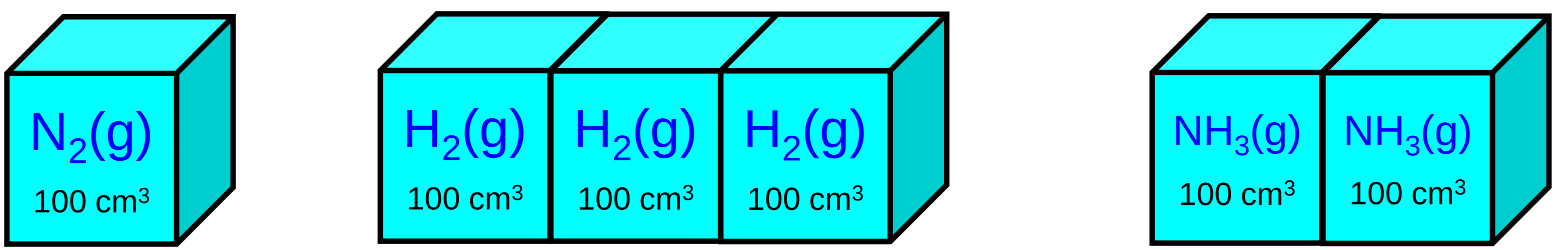


- **Avogadro's Law:** Identical volumes of gases, at the same temperature and pressure, contain identical numbers of molecules.

Measuring the Amount of a Gas

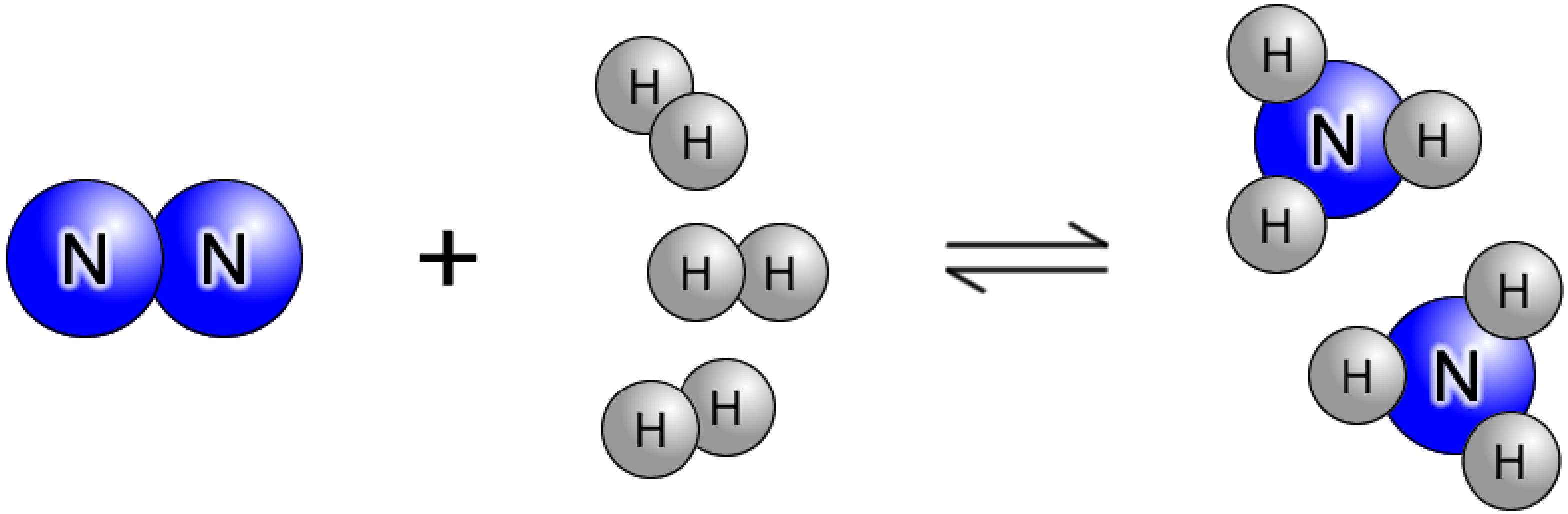


$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

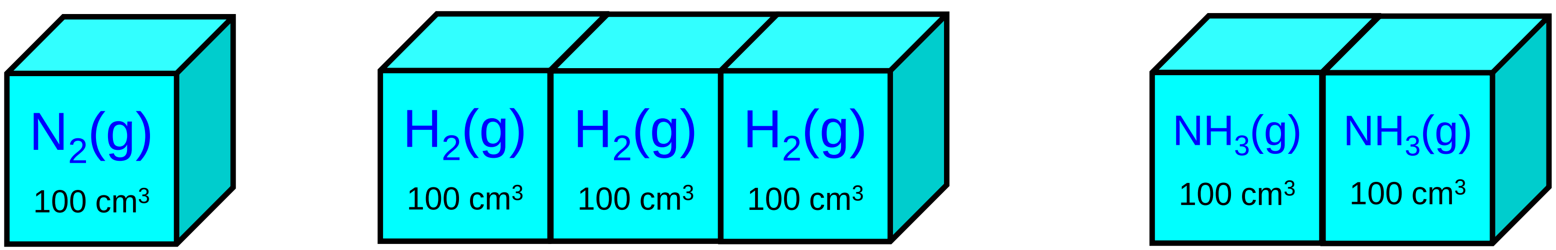


- *One mole* of $N_2(g)$ react with *three moles* of $H_2(g)$ to produce *two moles* of $NH_3(g)$.

Measuring the Amount of a Gas

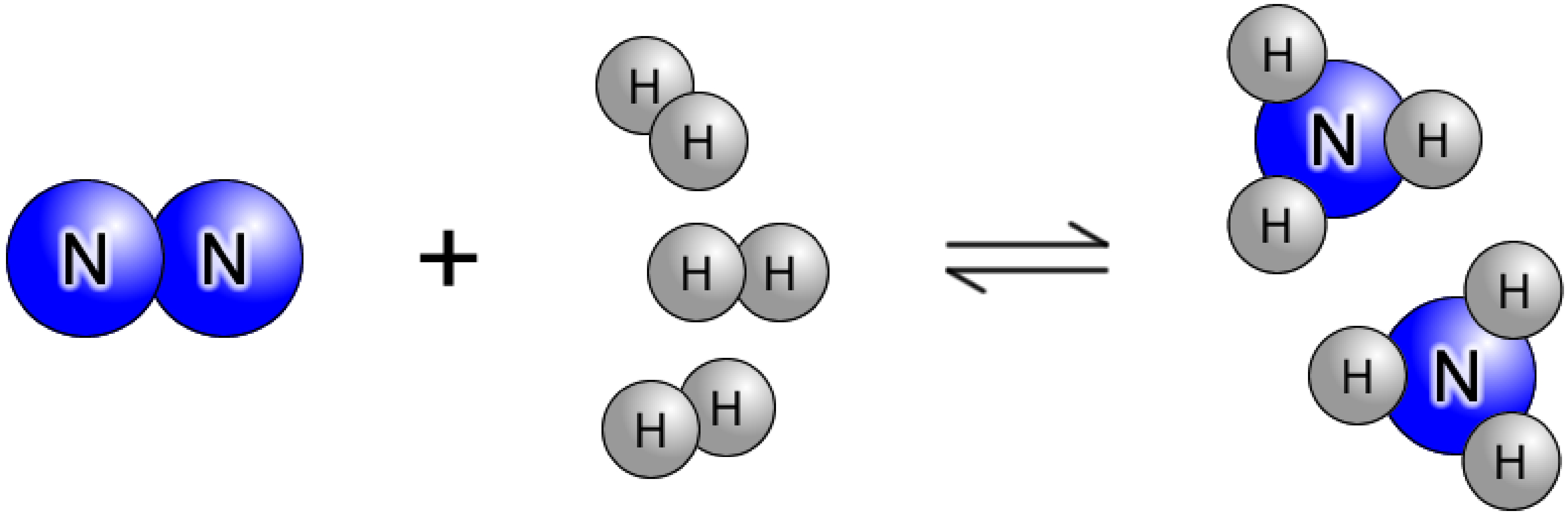


$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

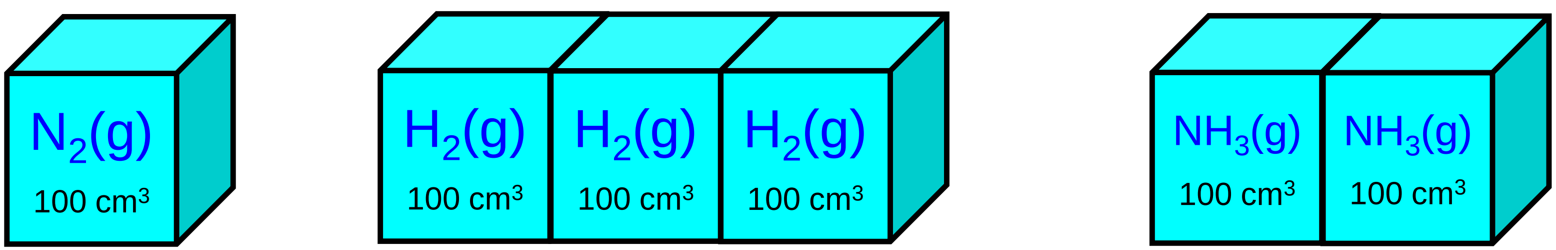


- There are *three times* more molecules of H_2(g) that there are N_2(g), and there are *two times* more molecules of NH_3(g) than there are N_2(g).

Measuring the Amount of a Gas

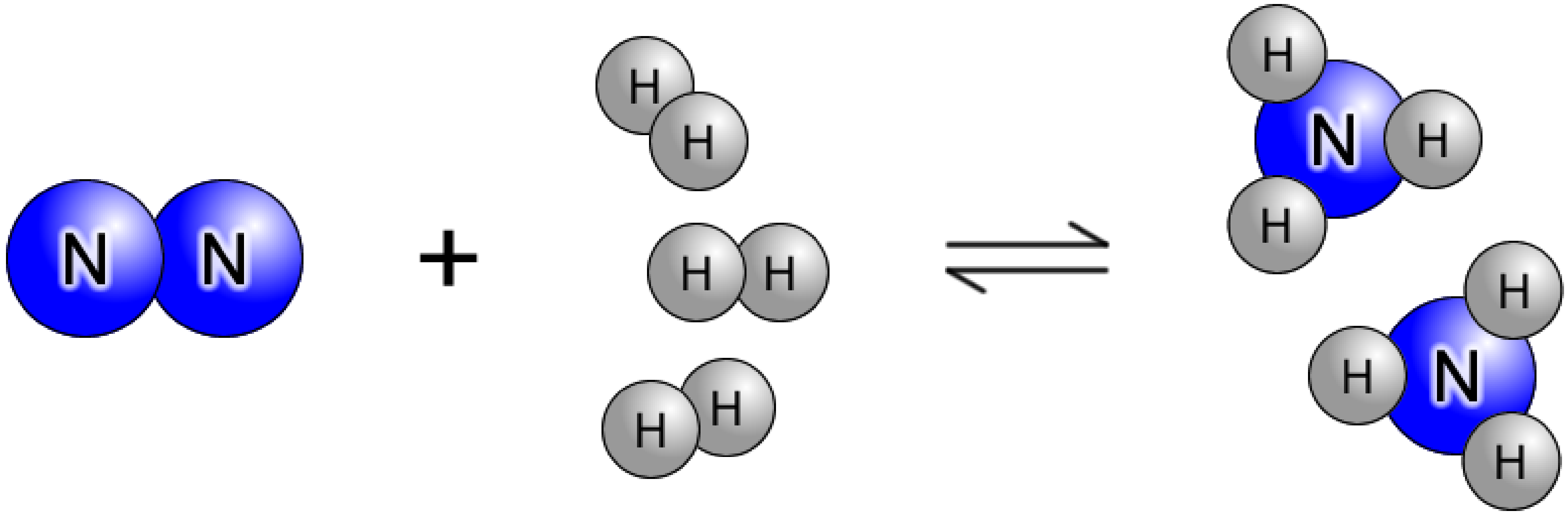


$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

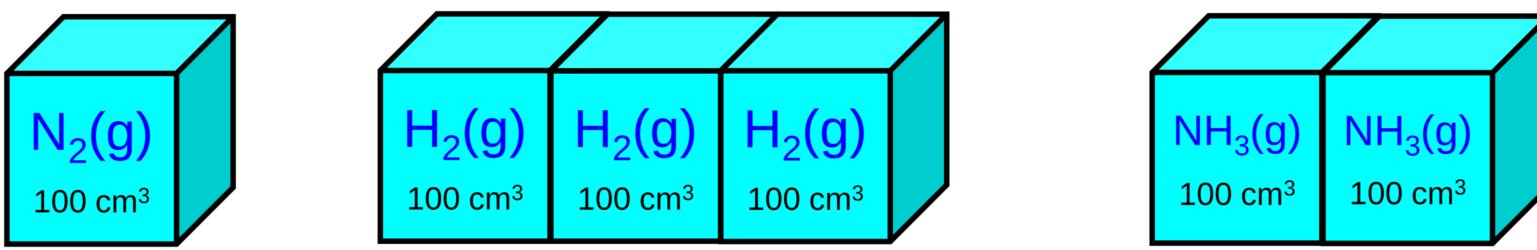


- Therefore, the volume of H_2(g) is *three times* the volume of N_2(g), and the volume of NH_3(g) is *two times* the volume of N_2(g).

Measuring the Amount of a Gas



$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$



- Based upon Avogadro's Law, 100 cm^3 of $N_2(g)$ will react exactly with 300 cm^3 of $H_2(g)$ to produce 200 cm^3 of $NH_3(g)$.

Molar Volume of Gas

Can you remember what you learnt about *gases* during *kinetic particle theory*?

Molar Volume of Gas

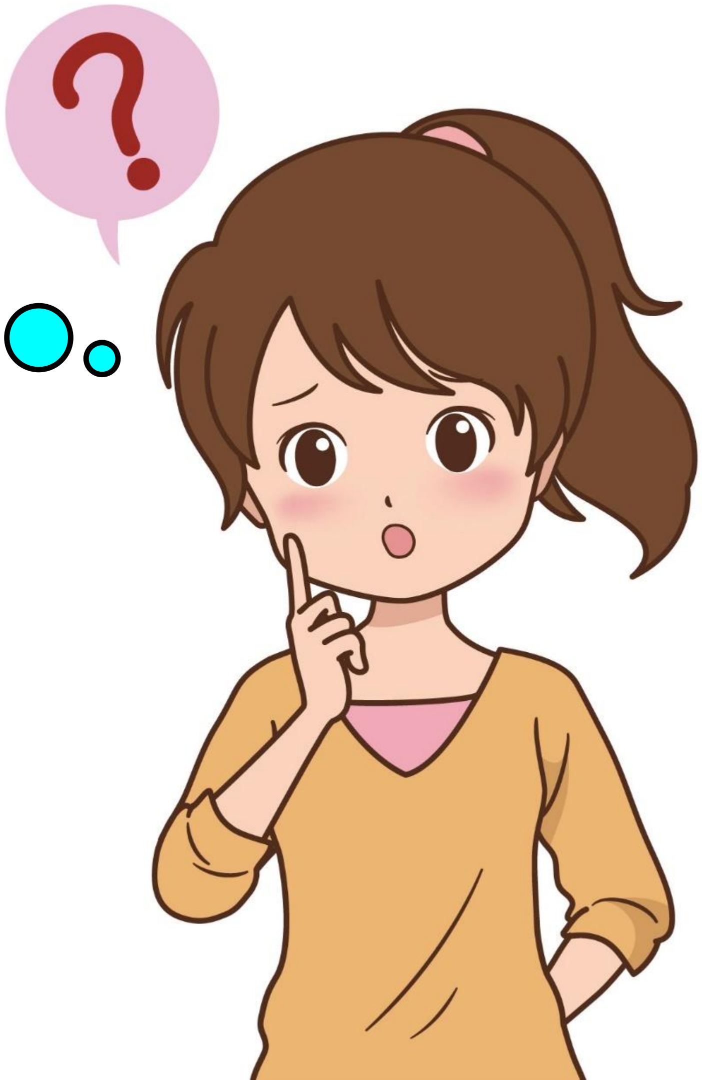
- What is the relationship between the *volume* of each gas molecule and the *average distance* between one molecule and its neighbours?

Molar Volume of Gas

- The molecules in a gas are moving in a very randomly / chaotic manner. There is a *large separation* between the molecules.
- The volume of each molecule is *insignificant* (point mass) compared to their separation.

Molar Volume of Gas

So, what is the *consequence* of this?



Molar Volume of Gas

- All gases, regardless of their chemical composition, *occupy the same volume* at room temperature and pressure because they contain the *same number of molecules* with the *same average separation* between them. The volume of the actual gas molecules themselves is *insignificant*.

Molar Volume of Gas

- *1 mol* of gas occupies *24 dm^3* (or *24 000 cm^3*) at room temperature and pressure.

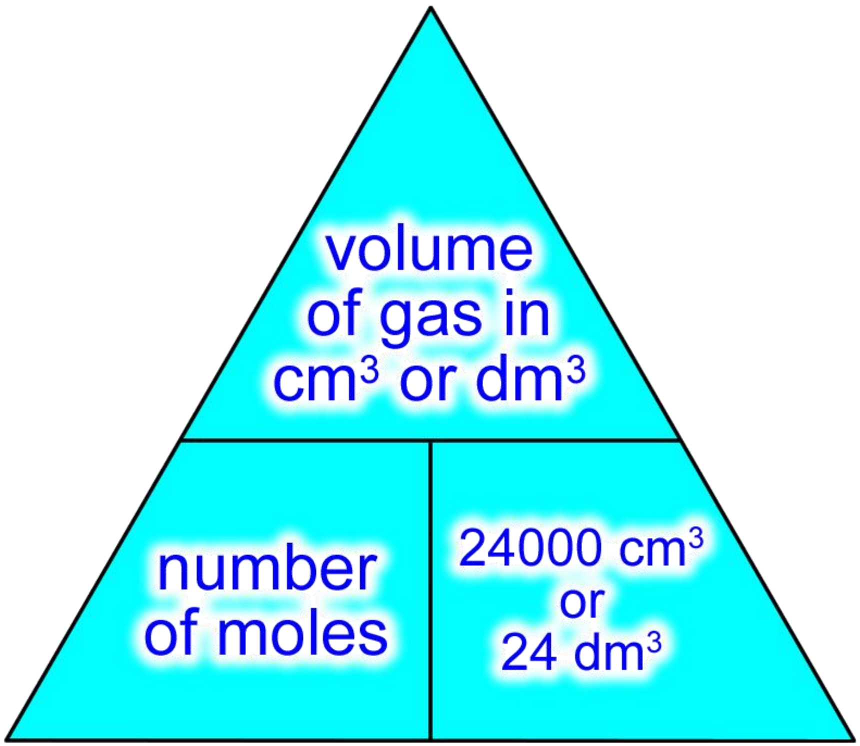
Molar Volume of Gas

Why specify *room temperature* and *pressure*?

Molar Volume of Gas

- Room temperature and pressure is normally taken to be 25.0 °C (273 K) and 1 atmosphere (101 000 pa).
- This must be specified because, at any other temperature and / or pressure, a gas will expand or contract to *occupy* a *different volume*.
- High temperatures and / or low pressures will cause a gas to *expand* and occupy a larger volume.
- Low temperatures and / or high pressures will cause a gas to *contract* and occupy a smaller volume.

Molar Volume of Gas

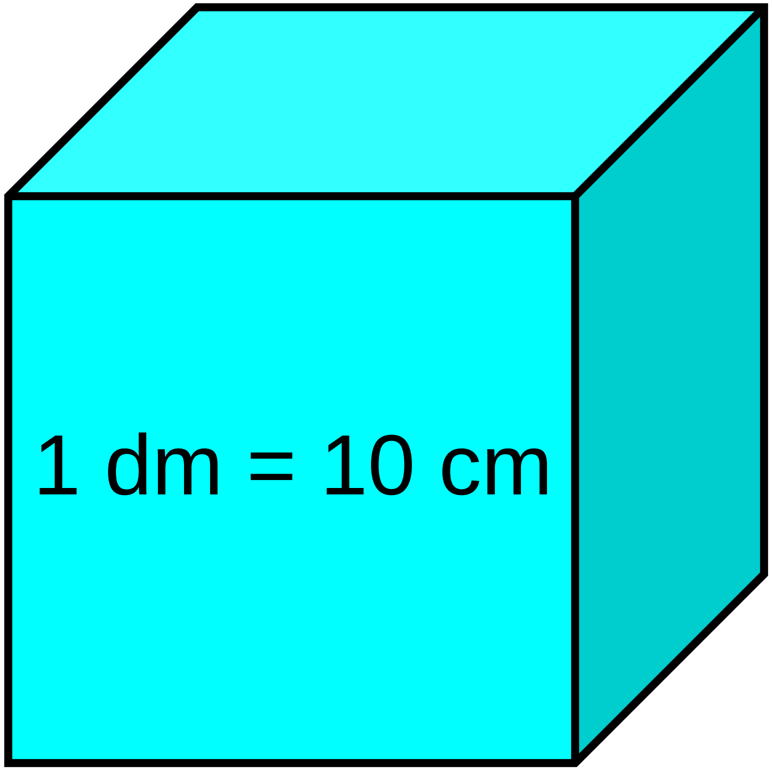


- moles = volume of gas in cm^3 or dm^3 ÷ 24000 cm^3 or 24 dm^3
- volume of gas in cm^3 or dm^3 = moles × 24000 cm^3 or 24 dm^3
- 24000 cm^3 or 24 dm^3 = volume of gas in cm^3 or dm^3 ÷ moles

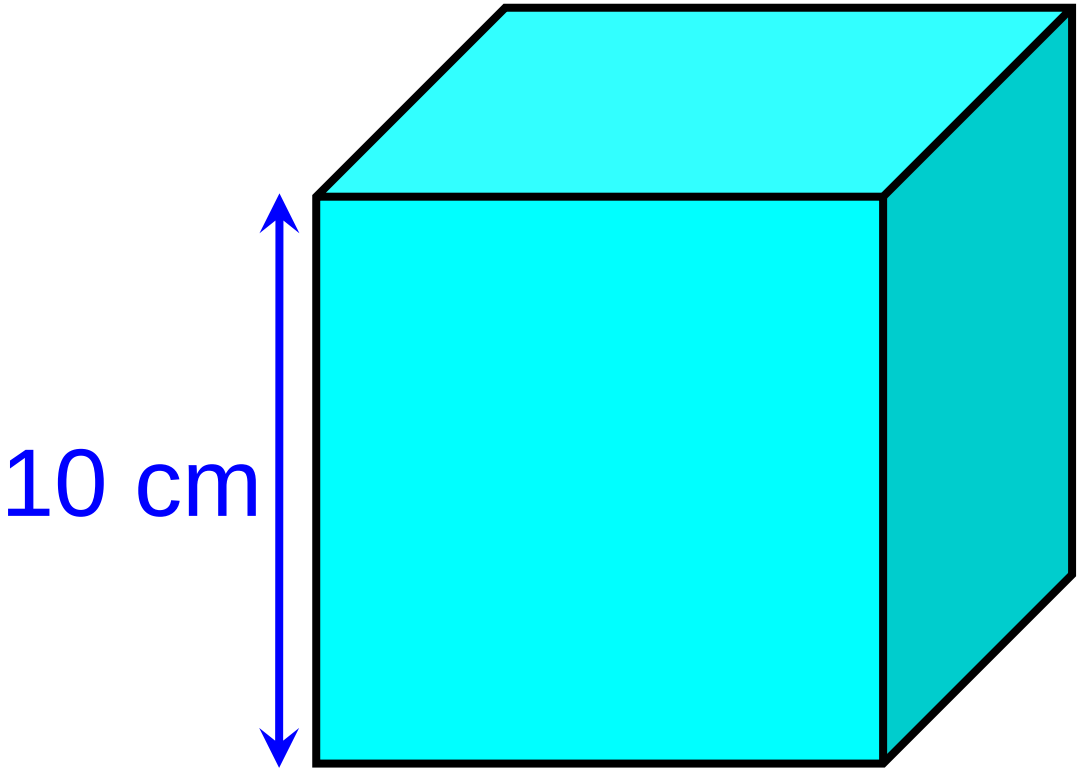
Molar Volume of Gas

What is a
decimetre cubed
(*dm^3*)?

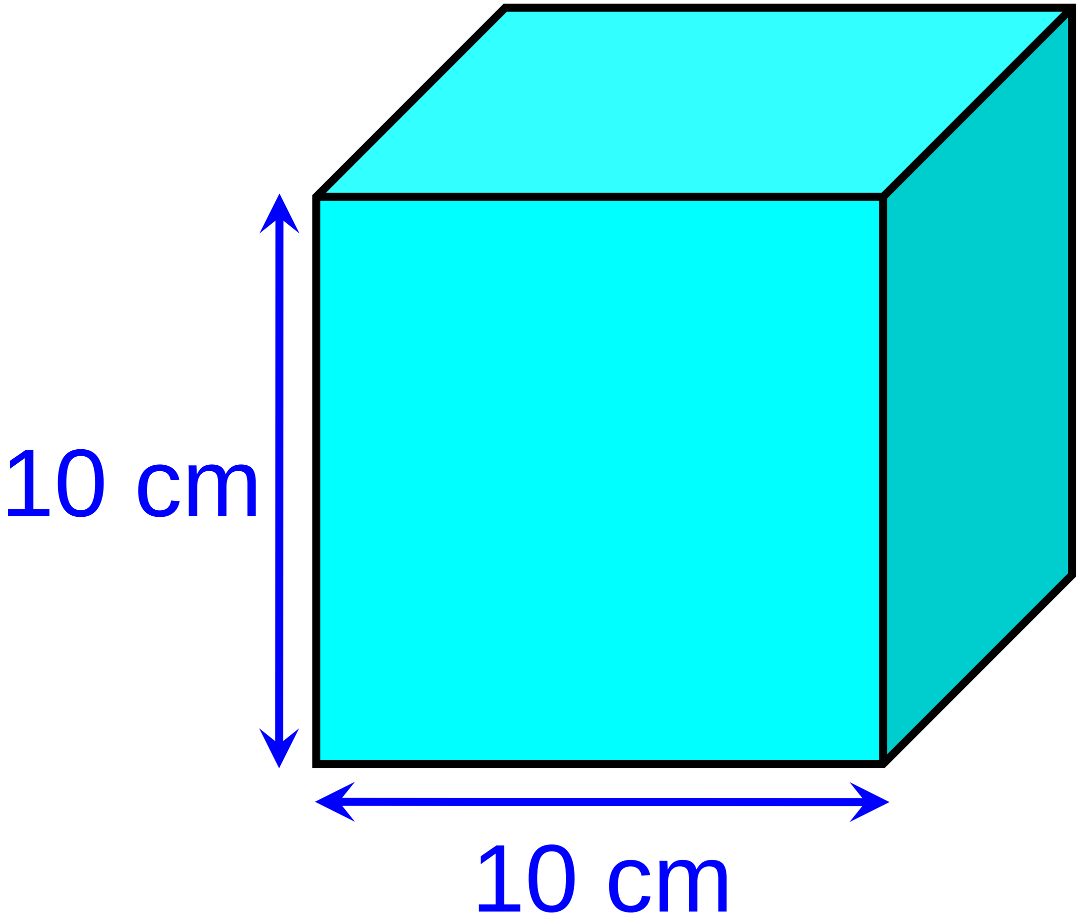
Molar Volume of Gas



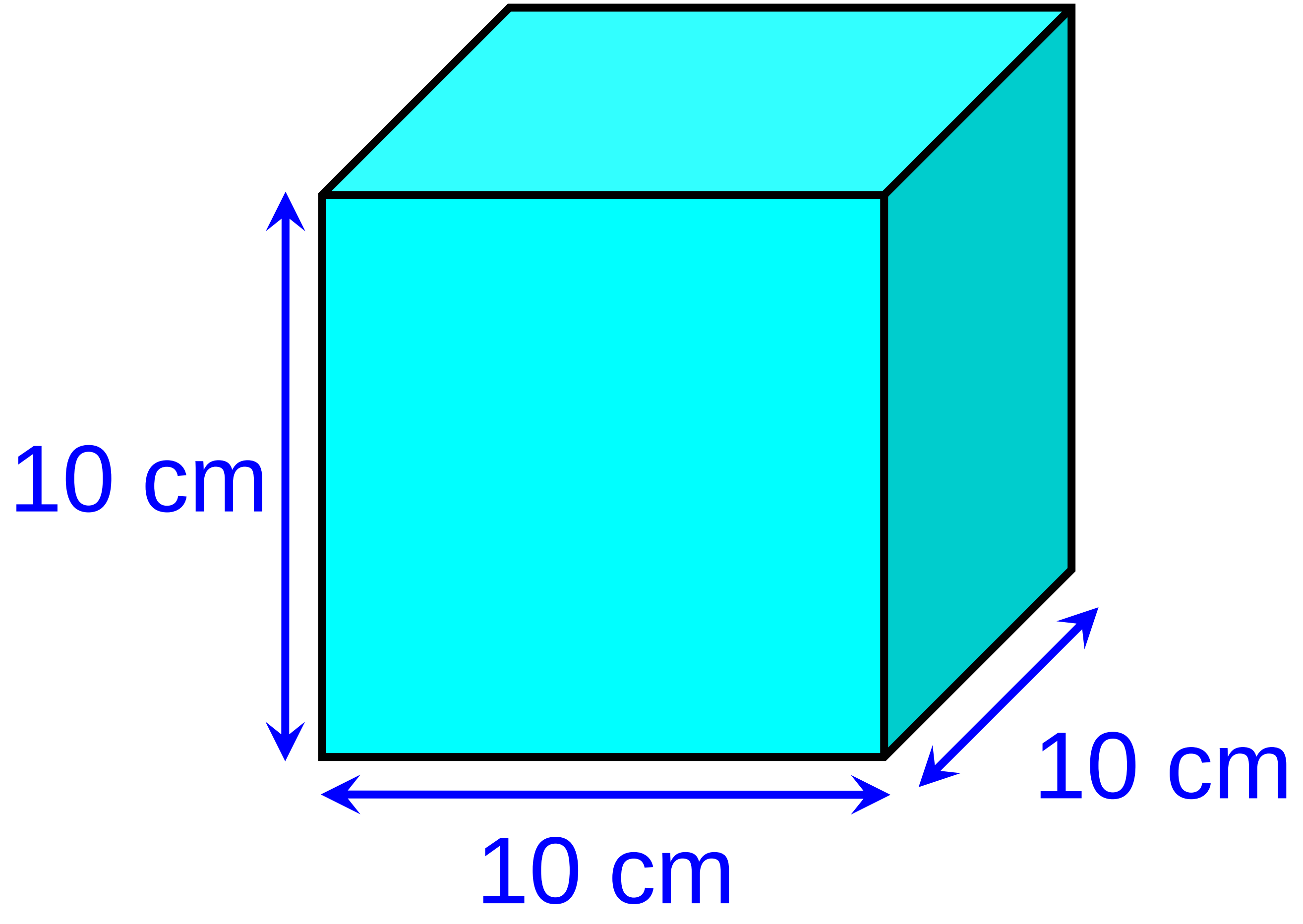
Molar Volume of Gas



Molar Volume of Gas

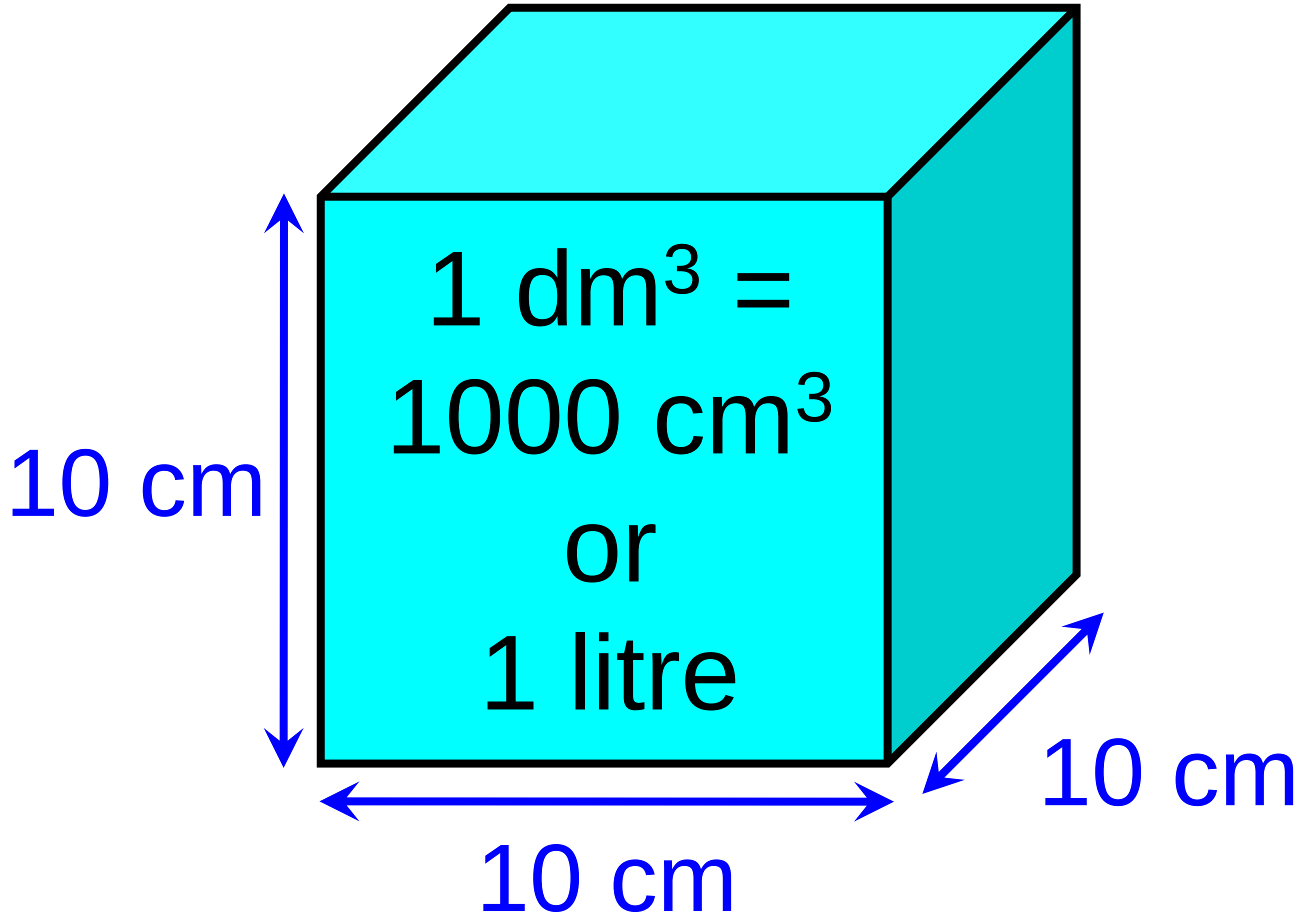


Molar Volume of Gas



$$10 \times 10 \times 10 = 1000$$

Molar Volume of Gas



$$10 \times 10 \times 10 = 1000$$

Molar Volume of Gas

Can I have some questions to help me check my understanding?

Molar Volume of Gas

Question 1.

ethane + oxygen → carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 1) Calculate the number of moles of ethane that burn completely in oxygen.

Molar Volume of Gas

Question 1.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 1) Calculate the number of moles of ethane that burn completely in oxygen.

- moles of gas = volume in $dm^3 \div 24.0\ dm^3$
- moles of ethane = $60.0\ dm^3 \div 24.0\ dm^3$
  = 2.50 mol

Molar Volume of Gas

Question 1.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 2) From the balanced chemical equation, calculate the number of moles of carbon dioxide produced from 2.50 mol of ethane.

Molar Volume of Gas

Question 1.

ethane + oxygen → carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 2) From the balanced chemical equation, calculate the number of moles of carbon dioxide produced from 2.50 mol of ethane.

- From the balanced chemical equation, 2 mol of ethane produce 4 mol of carbon dioxide

$\therefore$ 2.50 mol of ethane will produce $^4/_2 \times 2.50$ mol = 5.00 mol of carbon dioxide

Molar Volume of Gas

Question 1.

ethane + oxygen → carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 3) Calculate the volume occupied by 5.00 mol of carbon dioxide gas.

Molar Volume of Gas

Question 1.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 60.0 dm^3 of ethane burns completely in oxygen?

Step 3) Calculate the volume occupied by 5.00 mol of carbon dioxide gas.

- volume in dm^3 = moles of gas $\times$ 24.0 dm^3
- volume of carbon dioxide = 5.00 $\times$ 24.0 dm^3

  = <u>120</u> dm^3

Molar Volume of Gas

Question 2.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 1) Calculate the number of moles of ethane that are present in 84.0 dm^3 of ethane.

Molar Volume of Gas

Question 2.

ethane + oxygen → carbon dioxide + steam

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 1) Calculate the number of moles of ethane that are present in 84.0 dm^3 of ethane.

- moles of gas = volume in dm^3 ÷ 24.0 dm^3
- moles of ethane = 84.0 dm^3 ÷ 24.0 dm^3
  = 3.50 mol

Molar Volume of Gas

Question 2.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 2) From the balanced chemical equation, calculate the number of moles of oxygen that react with 3.50 mol of ethane.

Molar Volume of Gas

Question 2.

ethane + oxygen → carbon dioxide + steam

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 2) From the balanced chemical equation, calculate the number of moles of oxygen that react with 3.50 mol of ethane.

- From the balanced chemical equation, 2 mol of ethane react with 7 mol of oxygen

$\therefore$ 3.50 mol of ethane will react with $^7/_2 \times 3.50$ mol

= 12.25 mol of oxygen

Molar Volume of Gas

Question 2.

ethane + oxygen → carbon dioxide + steam

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 3) Calculate the volume occupied by 12.25 mol of oxygen gas.

Molar Volume of Gas

Question 2.

ethane + oxygen $\rightarrow$ carbon dioxide + steam

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

What volume of oxygen gas is required to completely react with 84.0 dm^3 of ethane?

Step 3) Calculate the volume occupied by 12.25 mol of oxygen gas.

- volume in dm^3 = moles of gas $\times$ 24.0 dm^3
- volume of carbon dioxide = 12.25 $\times$ 24.0 dm^3
  = 294 dm^3

Molar Volume of Gas

Question 3.

glucose + oxygen → carbon dioxide + steam

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 1) Calculate the relative molecular mass of glucose.

Molar Volume of Gas

Question 3.

glucose + oxygen → carbon dioxide + steam

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 1) Calculate the relative molecular mass of glucose.

- M_r of $C_6H_{12}O_6 = (6 \times 12.0) + (12 \times 1.0) + (6 \times 16.0)$
- M_r of $C_6H_{12}O_6 = 72.0 + 12.0 + 96.0$
- M_r of $C_6H_{12}O_6 = 180$

Molar Volume of Gas

Question 3.

glucose + oxygen $\rightarrow$ carbon dioxide + steam

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 2) Calculate the number of moles of glucose that are present in 135 g of glucose.

Molar Volume of Gas

Question 3.

glucose + oxygen $\rightarrow$ carbon dioxide + steam

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 2) Calculate the number of moles of glucose that are present in 135 g of glucose.

- moles of compound = mass in g ÷ relative molecular mass

- moles of glucose = 135 g ÷ 180
  = 0.750 mol

Molar Volume of Gas

Question 3.

glucose + oxygen $\rightarrow$ carbon dioxide + steam

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 3) From the balanced chemical equation, calculate the number of moles of carbon dioxide that are produced from 0.750 mol of glucose.

Molar Volume of Gas

Question 3.

glucose + oxygen → carbon dioxide + steam

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 3) From the balanced chemical equation, calculate the number of moles of carbon dioxide that are produced from 0.750 mol of glucose.

- From the balanced chemical equation, 1 mol of glucose produces 6 mol of carbon dioxide

$\therefore$ 0.750 mol of ethane will produce $^6/_1 \times 0.750$ mol
= 4.50 mol of carbon dioxide

Molar Volume of Gas

Question 3.

glucose + oxygen $\rightarrow$ carbon dioxide + steam

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 4) Calculate the volume occupied by 4.50 mol of carbon dioxide gas.

Molar Volume of Gas

Question 3.

glucose + oxygen → carbon dioxide + steam

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

What volume of carbon dioxide gas is produced when 135 g of glucose burns completely in oxygen?

Step 4) Calculate the volume occupied by 4.50 mol of carbon dioxide gas.

- volume in dm^3 = moles of gas $\times$ 24.0 dm^3
- volume of carbon dioxide = $4.50 \times 24.0\ dm^3$
  = $\underline{108}\ dm^3$

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Molar Volume of Gas

Question 4.

carbon dioxide + calcium hydroxide $\rightarrow$ calcium carbonate + water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 1) Calculate the number of moles of carbon dioxide that are bubbled into the limewater.

Molar Volume of Gas

Question 4.

carbon dioxide + calcium hydroxide → calcium carbonate + water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 1) Calculate the number of moles of carbon dioxide that are bubbled into the limewater.

- moles of gas = volume in $dm^3 \div 24.0\ dm^3$
- moles of carbon dioxide = $43.2\ dm^3 \div 24.0\ dm^3$
  = 1.80 mol

Molar Volume of Gas

Question 4.

carbon dioxide + calcium hydroxide $\rightarrow$ calcium carbonate + water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 2) From the balanced chemical equation, calculate the number of moles of calcium carbonate produced from 1.80 mol of carbon dioxide.

Molar Volume of Gas

Question 4.

carbon dioxide + calcium hydroxide → calcium carbonate + water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 2) From the balanced chemical equation, calculate the number of moles of calcium carbonate produced from 1.80 mol of carbon dioxide.

- From the balanced chemical equation, 1 mol of carbon dioxide produce 1 mol of calcium carbonate

$\therefore$ 1.80 mol of carbon dioxide will produce

$^1/_1 \times 1.80$ mol $=$ 1.80 mol of calcium carbonate

Molar Volume of Gas

Question 4.

carbon dioxide	+	calcium hydroxide	$\rightarrow$	calcium carbonate	+	water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 3) Calculate the mass in grams of 1.80 mol of calcium carbonate.

Molar Volume of Gas

Question 4.

carbon dioxide + calcium hydroxide → calcium carbonate + water

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

What mass of calcium carbonate is produced when 43.2 dm^3 of carbon dioxide gas are bubbled into limewater?

Step 3) Calculate the mass in grams of 1.80 mol of calcium carbonate.

- mass in grams = $M_r \times$ moles
- mass of calcium carbonate = $(40 + 12 + (3 \times 16)) \times 1.80$
- mass of calcium carbonate = $100 \times 1.80 = \underline{180}$ g

Molar Volume of Gas

Question 5.

- *Hydrocarbons* are compounds that contain the two chemical elements *hydrogen* and *carbon* only.
- When hydrocarbons undergo complete combustion, they react with *oxygen* to produce *carbon dioxide* and *water* as the only reaction products.
- Using x to represent the number of carbon atoms and y to represent the number of hydrogen atoms, write the general equation for the complete combustion of a hydrocarbon.

Molar Volume of Gas

Question 5.

- *Hydrocarbons* are compounds that contain the two chemical elements *hydrogen* and *carbon* only.

- When hydrocarbons undergo complete combustion, they react with *oxygen* to produce *carbon dioxide* and *water* as the only reaction products.

- Using x to represent the number of carbon atoms and y to represent the number of hydrogen atoms, write the general equation for the complete combustion of a hydrocarbon.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

- $25.0\ cm^3$ of a gaseous hydrocarbon underwent complete combustion in air to produce carbon dioxide gas and water vapour.
- On cooling to room temperature and pressure (r.t.p.), the volume of gaseous product contracted by $100\ cm^3$.
- After bubbling through aqueous sodium hydroxide, the volume of gaseous product contracted again by $100\ cm^3$.
- Calculate the formula of the hydrocarbon.

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 1) Calculate moles of hydrocarbon burnt.

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 1) Calculate moles of hydrocarbon burnt.

- volume of hydrocarbon burnt = 25.0 cm^3
- moles of gas = volume in cm^3 ÷ 24 000
- moles of hydrocarbon = 25.0 ÷ 24 000 = 0.00104 mol

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 2) Calculate moles of H atoms in the hydrocarbon.

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 2) Calculate moles of H atoms in the hydrocarbon.

- When the gaseous product is cooled to r.t.p., the volume decreases because the water vapour condenses.
- volume of H_2O(g) = 100 cm^3
- moles of gas = volume in cm^3 ÷ 24 000
- moles of H_2O(g) = 100 ÷ 24 000 = 0.00417 mol
- 1 mol of H_2O(g) contains 2 mol of H atoms
- moles of H atoms in the hydrocarbon
  = 2 × 0.00417 = 0.00834 mol

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 3) Calculate moles of C atoms in the hydrocarbon.

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 3) Calculate moles of C atoms in the hydrocarbon.

- Alkaline sodium hydroxide removes acidic carbon dioxide gas from the gaseous product.
- volume of CO_2(g) = 100 cm^3
- moles of gas = volume in $cm^3 \div 24\,000$
- moles of CO_2(g) = $100 \div 24\,000$ = 0.00417 mol
- 1 mol of CO_2(g) contains 1 mol of C atoms
- moles of C atoms in the hydrocarbon = 1×0.00417 = 0.00417 mol

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 4) Calculate the formula of the hydrocarbon.

Molar Volume of Gas

Question 5.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Step 4) Calculate the formula of the hydrocarbon.

- 0.00104 mol of gaseous hydrocarbon contains: 0.00834 mol of hydrogen atoms and 0.00417 mol of carbon atoms

- 1 mole of gaseous hydrocarbon contains 0.00834 ÷ 0.00104 = <u>8</u> mol of H atoms (whole number)

- 1 mole of gaseous hydrocarbon contains 0.00417 ÷ 0.00104 = <u>4</u> mol of C atoms (whole number)

- The formula of the hydrocarbon is C_4H_8

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 1) Calculate moles $C_xH_4(g)$ burnt.

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 1) Calculate moles $C_xH_4(g)$ burnt.

- moles of gas = volume in cm^3 ÷ 24 000
- moles of $C_xH_4(g)$ = 20.0 ÷ 24 000 = <u>0.000833</u> mol

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 2) Calculate moles H atoms in 0.000833 mol of C_xH_4(g).

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 2) Calculate moles H atoms in 0.000833 mol of C_xH_4(g).

- 1 mol of C_xH_4(g) contains 4 mol of H atoms
- 0.000833 mol of C_xH_4(g) contains 4×0.000833 = 0.00333 mol of H atoms

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 3) Calculate moles of $H_2O(g)$ produced from 0.00333 mol of H atoms.

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x+1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 3) Calculate moles of $H_2O(g)$ produced from 0.00333 mol of H atoms.

- 1 mol of $H_2O(g)$ contains 2 mol of H atoms
- moles of $H_2O(g)$ produced from 0.00333 mol of H atoms = 0.00333 ÷ 2 = <u>0.00167</u> mol of $H_2O(g)$

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 4) Calculate moles of $O_2(g)$ that reacted with the H atoms in $C_xH_4(g)$ to produce 0.00617 mol of $H_2O(g)$.

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 4) Calculate moles of $O_2(g)$ that reacted with the H atoms in $C_xH_4(g)$ to produce 0.00617 mol of $H_2O(g)$.

- 0.00167 mol of $H_2O(g)$ molecules contain <u>0.00167</u> mol of O atoms

- 0.00167 mol of O atoms originate from 0.00167 ÷ 2 = <u>0.000833</u> mol of $O_2(g)$

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x+1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 5) Calculate moles of $O_2(g)$ that reacted with $C_xH_4(g)$.

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 5) Calculate moles of $O_2(g)$ that reacted with $C_xH_4(g)$.

- moles of gas = volume in $cm^3 \div 24\,000$
- moles of $O_2(g)$ used for the complete combustion of $C_xH_4(g) = 60.0 \div 24\,000 = \underline{0.00250}$ mol

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 6) Calculate moles of $O_2(g)$ that reacted with the C atoms in $C_xH_4(g)$.

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 6) Calculate moles of $O_2(g)$ that reacted with the C atoms in $C_xH_4(g)$.

- moles of $O_2(g)$ that reacted with the C atoms in $C_xH_4(g)$ = total mol of $O_2(g)$ – mol of $O_2(g)$ reacted with H atoms
- moles of $O_2(g)$ that reacted with the C atoms in $C_xH_4(g)$ = 0.00250 – 0.000833 = $\underline{0.00167}$ mol

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Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 7) Calculate moles of C atoms in the hydrocarbon, *i.e.* mol of C atoms that react with 0.00167 mol of O_2(g).

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 7) Calculate moles of C atoms in the hydrocarbon, *i.e.* mol of C atoms that react with 0.00167 mol of O_2(g).

- C reacts with O_2 to form CO_2 in a 1:1 ratio:

$$C + O_2 \rightarrow CO_2$$

- <u>0.00167</u> mol of C atoms in C_xH_4(g) react with 0.00167 mol of O_2(g) to produce 0.00167 mol of CO_2(g)

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 8) Calculate moles of C atoms in 1 mol of C_xH_4(g).

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

Step 8) Calculate moles of C atoms in 1 mol of $C_xH_4(g)$.

- 0.000833 mol of $C_xH_4(g)$ contains 0.00167 mol of C atoms

- 1 mol of $C_xH_4(g)$ contains $0.00167 \div 0.000833$ = <u>2</u> mol of C atoms (to the nearest whole number)

Molar Volume of Gas

Question 6.

- A hydrocarbon has the formula C_xH_4. 20.0 cm^3 of the hydrocarbon undergoes complete combustion with exactly 60.0 cm^3 of oxygen. Calculate the value of x and hence state the formula of the hydrocarbon.

$$C_xH_4(g) + (x + 1)O_2(g) \rightarrow xCO_2(g) + 2H_2O(g)$$

- the value of x in C_xH_4(g) = <u>2</u>
- the formula of the hydrocarbon is C_2H_4 (ethene)

Molar Volume of Gas

What advanced concepts are there for molar volume of gas?

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

P = pressure in Pascals / pa

V = volume in cubic metres / m^3

$1\ m^3 = 1\ 000\ 000\ cm^3$

n = moles of gas / mol

T = temperature in Kelvin / K

$K = °C + 273$

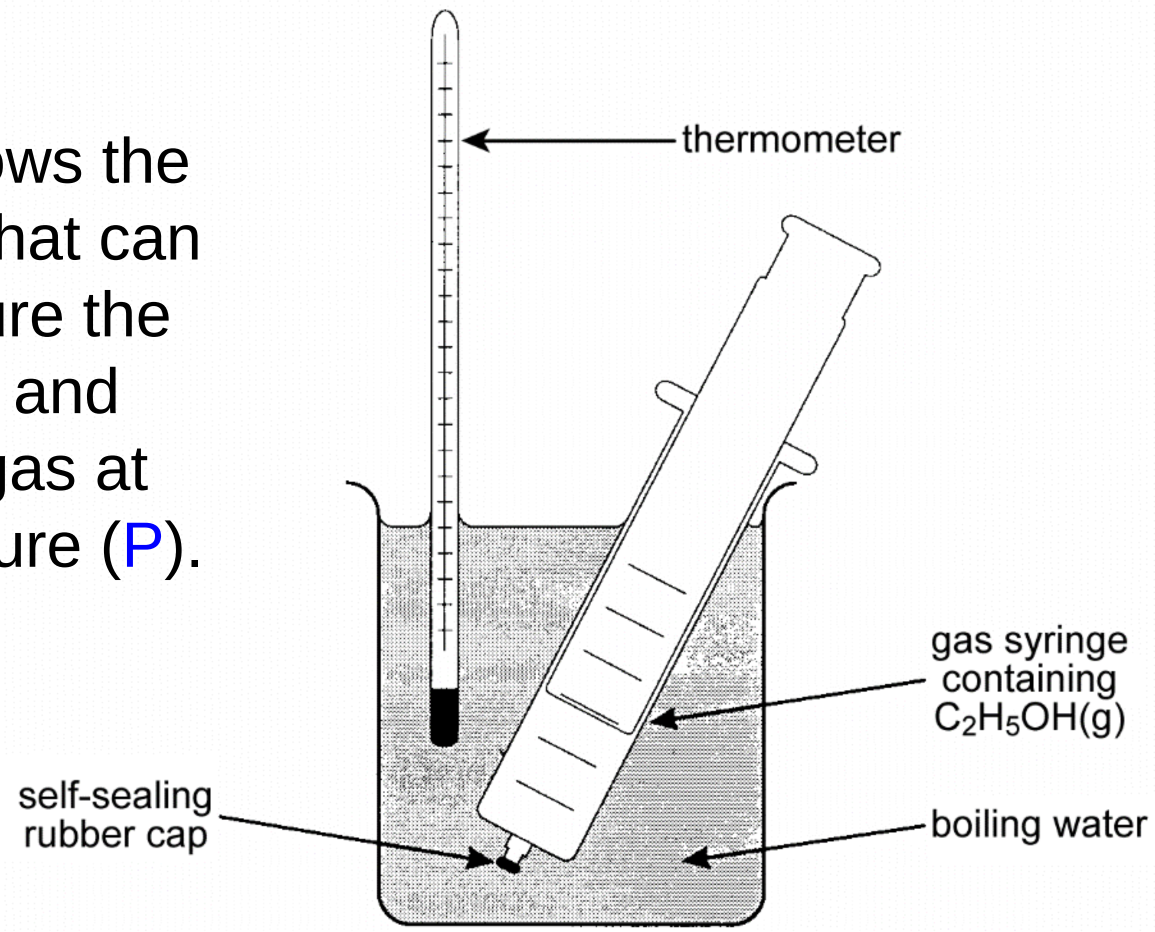
R = gas constant = 8.314 J/K/mol

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- The diagram shows the simple apparatus that can be used to measure the temperature (T) and volume (V) of a gas at atmospheric pressure (P).

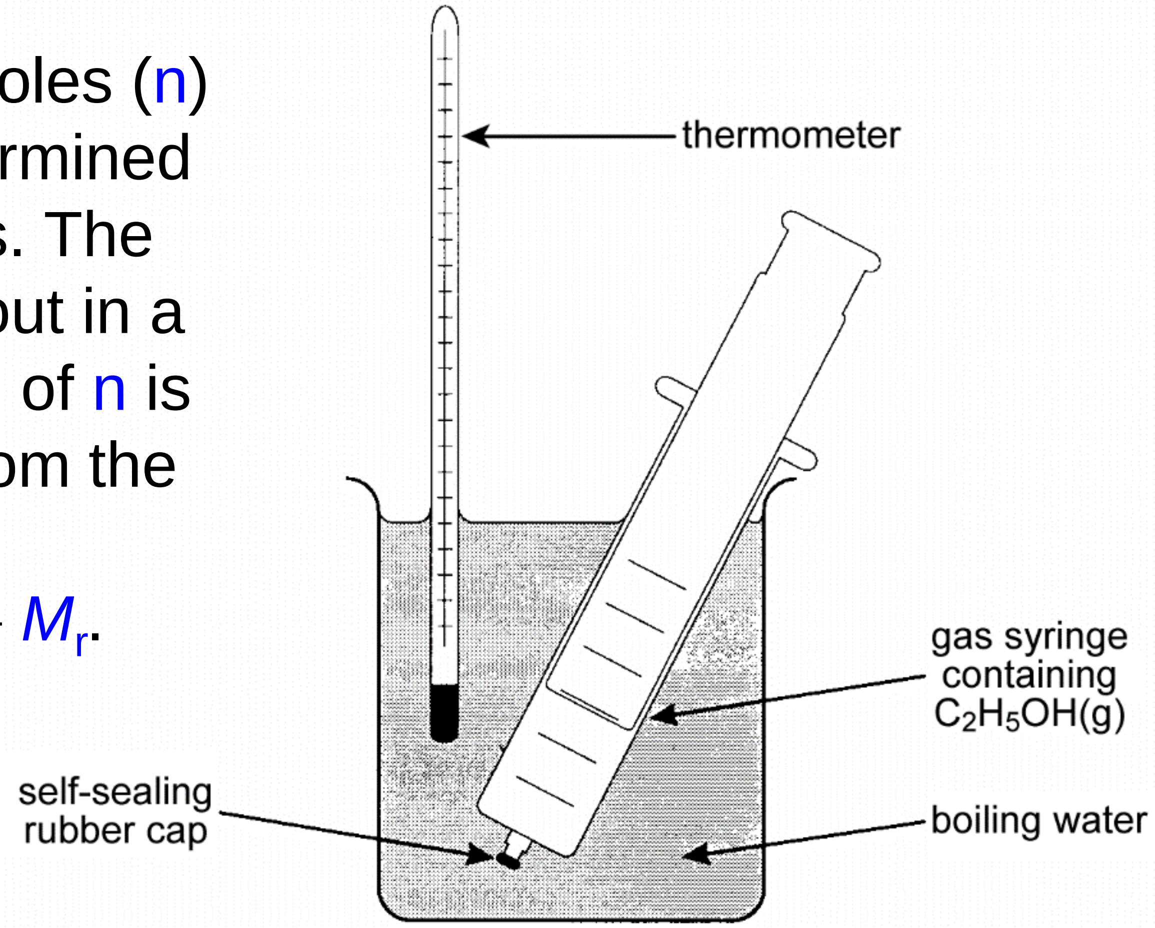


Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- The number of moles (n) can be easily determined for volatile liquids. The liquid is weighed out in a syringe. The value of n is then calculated from the formula:
  $n = \text{mass in g} \div M_r$.

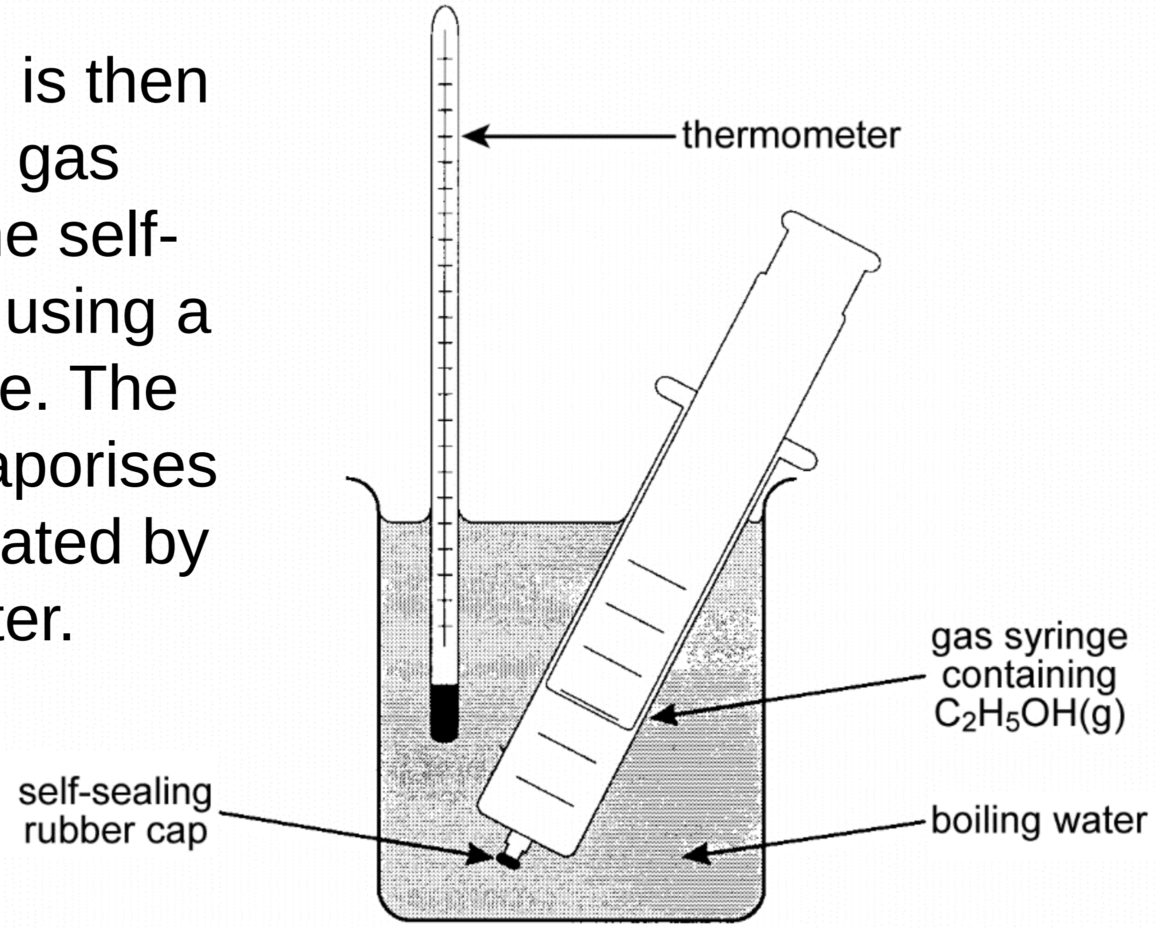


Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- The volatile liquid is then injected into the gas syringe through the self-sealing rubber cap using a hypodermic needle. The volatile liquid will vaporises into a gas when heated by the boiling water.



Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 1) Convert mass of ethanol into moles…

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 1) Convert mass of ethanol into moles…

- M_r $C_2H_5OH = (2 \times 12) + (6 \times 1) + 16$

  M_r $C_2H_5OH = 46.0$
- moles of ethanol = mass in grams ÷ M_r

  moles of ethanol = 0.167 ÷ 46.0

  moles of ethanol = <u>0.00363 mol</u>

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 2) Convert temperature in degrees Celsius into Kelvin…

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 2) Convert temperature in degrees Celsius into Kelvin…

- temperature in K = temperature in °C + 273

temperature in K = 100 + 273

temperature in K = 373 K

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 3) Rearrange equation to make volume of gas the subject of the equation…

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 3) Rearrange equation to make volume of gas the subject of the equation…

$$V = \frac{n \times R \times T}{P}$$

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 4) Calculate the volume of gaseous ethanol in cubic metres…

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 4) Calculate the volume of gaseous ethanol in cubic metres…

$$V = \frac{0.00363 \times 8.314 \times 373}{101\,300}$$

$\underline{0.000111\ m}^3$

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 5) Calculate the volume of gaseous ethanol in cubic centimetres…

Molar Volume of Gas

The Ideal Gas Equation

$$P \times V = n \times R \times T$$

- **Question**: 0.167 g of ethanol, formula C_2H_5OH, were heated to 100 °C at a pressure of 101 300 Pa. Calculate the volume, in cm^3, occupied by the ethanol.

Step 5) Calculate the volume of gaseous ethanol in cubic centimetres…

- 1.00 m^3 = 1 000 000 cm^3

$\therefore$ 0.000111 m^3 = 0.000111 × 1 000 000 cm^3

= $\underline{111\ cm}^3$

$\therefore$ volume of ethanol = $\underline{111\ cm}^3$

Molar Volume of Gas

Presentation on
Molar Volume of Gas

by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

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"When I was five years old, my mother always told me that happiness was the key to life. When I went to school, they asked me what I wanted to be when I grew-up. I wrote down 'happy'. They told me I didn't understand the assignment, and I told them they didn't understand life."

John Lennon