PROSPERITY ACADEMY

# AS CHEMISTRY 9701

# Crash Course

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# IDEAL GASES

## COMPLETE NOTES

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# States of matter

## Gaseous state: Ideal and real gases

### Kinetic theory of gases:-

1) Particles are in continous random motion
2) Particles behave as rigid spheres
3) Pressure of the gas is due to the collision between particles and the walls of the container.
4) All collisions are perfectly elastic, there is no loss of Kinetic energy
*5) The intermolecular forces between particles are negligible
*6) The volume occupied by the particles themselves is negligible compared to the volume of the container.

- In reality, no gas follows complete ideal behaviour
- At low temperatures or high pressures, the particles get close together which causes the intermolecular forces to increase and volume occupied by gas to become comparable to the volume of the particles ⟶ gas deviates from ideal behaviour.

# The ideal gas equation :-

① $\boxed{pV = nRT}$

- p is pressure in $Pa$
- V is volume in $m^3$
- n is number of moles
- R is molar gas constant = $8.31\ JK^{-1}mol^{-1}$
- T is Absolute temperature in K.

Conversions (Remember these)

* $1atm = 1.013 \times 10^5\ Pa$
* $1cm^3 = 10^{-6}\ m^3$
* $1dm^3 = 10^{-3}\ m^3$
* $K = C + 273$

- $PV = nRT$

$PV = \frac{m}{M_r/A_r} \times R \times T$

② $\boxed{M_r/A_r = \frac{m \times R \times T}{p \times V}}$

- $PV = nRT$

$P = \frac{n}{V} \times R \times T$ $\left(\frac{n}{V} = \text{concentration in } mol/m^3\right)$

③ $\boxed{P = c \times R \times T}$

## Constant pressure :-

$$pV = nRT$$

$$\frac{V}{T} = \frac{nR}{p} \Big] \text{const}$$

$$\frac{V_1}{T_1} = \text{const} = \frac{V_2}{T_2}$$

## Constant temperature :-

$$pV = nRT \Big]_{\text{const}}$$

$$p_1 V_1 = \text{const} = p_2 V_2$$

* Learning these is not necessary.

## Constant volume :-

$$pV = nRT$$

$$\frac{p}{T} = \frac{nR}{V} \Big] \text{const}$$

$$\frac{p_1}{T_1} = \text{const} = \frac{p_2}{T_2}$$

**13** At room temperature and pressure chlorine does not behave as an ideal gas.

At which temperature and pressure would the behaviour of chlorine become more ideal?

| | pressure /kPa | temperature /K |
|---|---|---|
| **A** | 50 | 200 |
| **B** | 50 | 400 |
| **C** | 200 | 200 |
| **D** | 200 | 400 |

ideal:
pressure ↓
temp ↑

**20** Iodine is a black, shiny, non-metallic solid and a member of Group VII. It sublimes easily on heating to give a purple vapour.

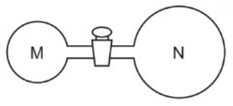
A sample of iodine vapour of mass 6.35 g has a volume of 1.247 $dm^3$ when maintained at constant temperature and a pressure of $1.00 \times 10^5$ Pa.

If iodine vapour acts as an ideal gas, what is the temperature of the iodine vapour?

**A** 300 K **B** 600 K **C** 300 000 K **D** 600 000 K

$pV = nRT$
$pV = \frac{m}{M_r} \times R \times T$
$(1\times10^5)(1.247\times10^{-3}) = \frac{6.35}{2(126.9)} \times 8.31 \times T$
$T = 599\,K$

**21** Two glass vessels M and N are connected by a closed valve.




M contains helium at 20 °C at a pressure of $1 \times 10^5$ Pa. N has been evacuated, and has three times the volume of M. In an experiment, the valve is opened and the temperature of the whole apparatus is raised to 100 °C.

What is the final pressure in the system?

**A** $3.18 \times 10^4$ Pa
**B** $4.24 \times 10^4$ Pa
**C** $1.25 \times 10^5$ Pa
**D** $5.09 \times 10^5$ Pa

$8.31(293.15)$
$8.31(373.15)$
$P = 31822$ Pa

**14** The gas laws can be summarised in the ideal gas equation.

$$pV = nRT$$

0.56 g of ethene gas is contained in a vessel at a pressure of 102 kPa and a temperature of 30 °C.

What is the volume of the vessel?

**A** 49 $cm^3$ **B** 494 $cm^3$ **C** 48 900 $cm^3$ **D** 494 000 $cm^3$

$pV = \frac{m}{M_r} \times R \times T$
$(102\times10^3)V = \frac{0.56}{28} \times 8.31 \times (30+273.15)$
$V = 4.94\times10^{-4}\ m^3$
$= 494\times10^{-6}\ m^3$

**4** Which mass of gas would occupy a volume of 3 $dm^3$ at 25 °C and 1 atmosphere pressure?
[1 mol of gas occupies 24 $dm^3$ at 25 °C and 1 atmosphere pressure.]

**A** 3.2 g $O_2$ gas $\frac{3.2}{32} = 0.1$
**B** 5.6 g $N_2$ gas $\frac{5.6}{28} = 0.2$
**C** 8.0 g $SO_2$ gas $\frac{8}{32+32} = 0.125$
**D** 11.0 g $CO_2$ gas $\frac{11}{12+32} = 0.25$

$pV = nRT$
$pV = \frac{m}{M_r} \times R \times T$
$(1.013\times10^5)(3\times10^{-3}) = \frac{m}{M_r} \times 8.31 \times (25+273.15)$
$\frac{m}{M_r} = 0.1227$

**1** Flask X contains 1 $dm^3$ of helium at 2 kPa pressure and flask Y contains 2 $dm^3$ of neon at 1 kPa pressure.

$pV = nRT$
$(2\times10^3)(1\times10^{-3}) = n \times 8.31 \times T \Rightarrow n = \frac{2}{8.31T}$
$pV = nRT$
$(1\times10^3)(2\times10^{-3}) = n \times 8.31 \times T \Rightarrow n = \frac{2}{8.31T}$

If the flasks are connected at constant temperature, what is the final pressure?

**A** 1⅓ kPa **B** 1½ kPa **C** 1⅔ kPa **D** 2 kPa

$pV = nRT$
$p(3\times10^{-3}) = \frac{4}{8.31T} \times 8.31 \times T \Rightarrow p = \frac{4}{3\times10^{-3}} = 1333$ Pa

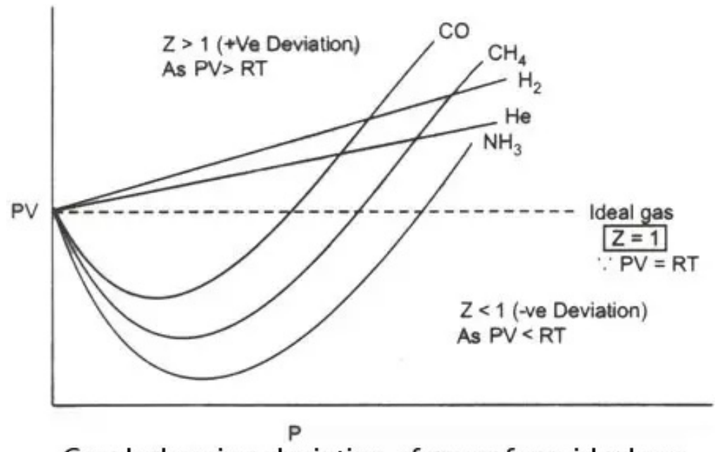
**22** When an evacuated glass tube of volume 200 $cm^3$ is filled with a gas at 300 K and 101 kPa, the mass of the tube increases by 1.06 g.

What is the identity of the gas?

**A** argon
**B** krypton
**C** neon
**D** xenon

$pV = nRT$
$(101\times10^3)(200\times10^{-6}) = \frac{1.06}{M_r}(8.31)(300)$
$M_r = 130.8$

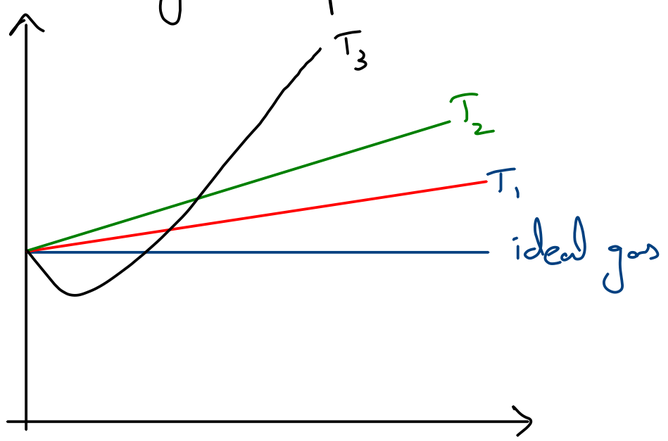
# Comparing ideality of gases:-



Graph showing deviation of gases from ideal gas

- He is most ideal as it only has temporary dipoles and 2 electrons.
- $H_2$ is more non ideal than He as it exists as a diatomic molecule (stronger temporary dipoles)
- $CH_4$ is more non ideal than $H_2$ as it has stronger temporary dipoles due to more number of electrons
- CO is more non ideal than $CH_4$ as it has permanent dipoles
- $NH_3$ is more non ideal than $CH_4$ as it has hydrogen bonding

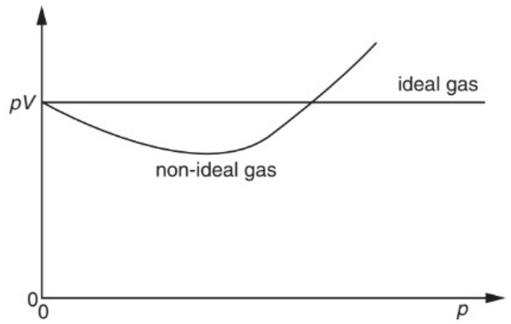
# Effect of temperature on ideality:-




$T_3 < T_2 < T_1$ as when temperature is lowered, particles come closer together

- → volume of particles no longer negligible
- → intermolecular forces get stronger.

**11** The value of $pV$ is plotted against $p$ for two gases, an ideal gas and a non-ideal gas, where $p$ is the pressure and $V$ is the volume of the gas.

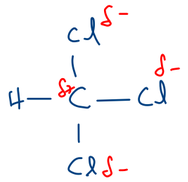



Which of the following gases shows the greatest deviation from ideality?

(A) ammonia perm. dipoles & hydrogen bonding
B ethene temp. dipoles
C methane temp. dipoles
D nitrogen temp. dipoles

**8** Which of the following least resembles an ideal gas?

(A) ammonia hydrogen bonding
B helium temp dipoles
C hydrogen temp dipoles
D trichloromethane perm. dipoles




**9** Which gas closely approaches ideal behaviour at room temperature and pressure?

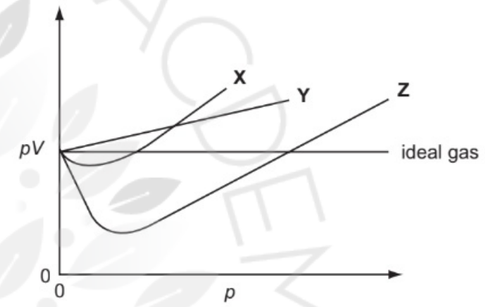
A ammonia
B carbon dioxide
(C) helium
D oxygen

**10** Which gas is likely to deviate most from ideal gas behaviour?

A $HCl$ perm dipoles
B He temp dipoles
C $CH_4$ temp dipoles
D $N_2$ temp dipoles

**15** For an ideal gas, the plot of $pV$ against $p$ is a straight line. For a real gas, such a plot shows a deviation from ideal behaviour. The plots of $pV$ against $p$ for three real gases are shown below.

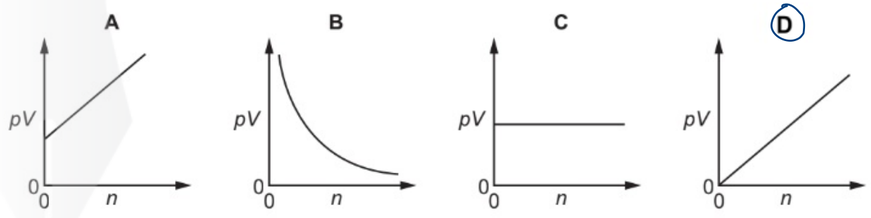
The gases represented are ammonia, hydrogen and nitrogen.




What are the identities of the gases **X**, **Y** and **Z**?

| | X | Y | Z |
|---|---|---|---|
| A | ammonia | nitrogen | hydrogen |
| B | hydrogen | nitrogen | ammonia |
| C | nitrogen | ammonia | hydrogen |
| (D) | nitrogen | hydrogen | ammonia |

**25** Which diagram shows the correct graph of $pV$ against $n$ for an ideal gas at constant temperature?




$pV = nRT \Rightarrow pV \propto n$ (R, T const)

**2** The kinetic theory of gases is used to explain the large scale (macroscopic) properties of gases by considering how individual molecules behave.

**(a)** State **two** basic assumptions of the kinetic theory as applied to an ideal gas.

**(i)** Negligible intermolecular forces between particles

**(ii)** Volume occupied by particles themselves is negligible compared to the volume of the container

[2]

**(b)** State **two** conditions under which the behaviour of a real gas approaches that of an ideal gas.

**(i)** low pressure

**(ii)** high temperature

[2]

**(c)** Place the following gases in decreasing order of ideal behaviour.

ammonia, neon, nitrogen

**most ideal** neon , nitrogen , ammonia **least ideal**

Explain your answer.

Nitrogen has more electrons than Neon so stronger temporary dipoles. Ammonia has hydrogen bonding which is the strongest.

[3]

**(d)** By using the kinetic-molecular model, explain why a liquid eventually becomes a gas as the temperature is increased.

As the temperature is increased, the particles start to move vigourously. The intermolecular forces between them get weak and they move further apart until the liquid becomes a gas

[2]

**(e)** Ethane, $CH_3CH_3$, and fluoromethane, $CH_3F$ are *iso*-electronic, that is they have the same total number of electrons in their molecules.

Calculate the **total** number of electrons in one molecule of $CH_3F$.

6 + 3 + 9 = 18 electrons

[1]

**(f)** The boiling points of these two compounds are given below.

| compound | bp/K |
|---|---|
| $CH_3CH_3$ | 184.5 |
| $CH_3F$ | 194.7 |

Suggest explanations for the following.

**(i)** the close similarity of the boiling points of the two compounds

Same number of electrons so temporary dipole forces are equally strong

**(ii)** the slightly higher boiling point of $CH_3F$

$CH_3F$ has permanent dipole forces too as it is a polar molecule.

[2]

[Total: 12]

When a 0.148 g sample of **A** was vapourised at 60°C, the vapour occupied a volume of 67.7 $cm^3$ at a pressure of 101 kPa.

Use the general gas equation $pV = nRT$ to calculate $M_r$ of **A**.

$$pV = \frac{m}{M_r} \times R \times T$$

$$(101 \times 10^3)(67.7 \times 10^{-6}) = \frac{0.148}{M_r} \times 8.31 \times (60 + 273)$$

$$M_r = 59.9$$