CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



EXAM QUESTION PACK

4 STATES OF MATTER

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Chapter 4

States of matter

4.1 The gaseous state: ideal and real gases and pV = nRT

167. 9701_m21_qp_12 Q: 6

A solution contains 0.25 g of sulfur dioxide in 1.00 dm^3 of water.

Which volume of sulfur dioxide, measured at 50 °C and a pressure of 1×10^5 Pa, must be added to 1.00 dm^3 of water to produce this solution?

A 0.0162 cm^3 **B** 0.105 cm^3 **C** 16.2 cm^3 **D** 105 cm^3

---

168. 9701_s21_qp_11 Q: 8

Which gas would behave most like an ideal gas under room conditions?

A helium

B nitrogen

C ammonia

D krypton

---

169. 9701_s21_qp_12 Q: 5

Flask Q contains 5 dm^3 of helium at 12 kPa pressure. Flask R contains 10 dm^3 of neon at 6 kPa pressure.

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

A 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa

---

170. 9701_w21_qp_11 Q: 6

Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?

A $CO_2(g)$ **B** $H_2(g)$ **C** Ne(g) **D** $NH_3(g)$

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171. 9701_w21_qp_12 Q: 8

The general gas equation can be used to calculate the value of the M_r of a gas.

For a sample of a gas of mass m grams, which expression will give the value of M_r?

A $M_r = \frac{mRT}{pV}$ **B** $M_r = \frac{pVRT}{m}$ **C** $M_r = \frac{mpV}{RT}$ **D** $M_r = \frac{pV}{mRT}$

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172. 9701_m20_qp_12 Q: 9

1.8 g of water, heated to 227 °C in a sealed container, turns to steam with a pressure of 200 kPa.

What is the approximate volume of the container?

A $9 \times 10^{-4}\,m^3$ **B** $2 \times 10^{-3}\,m^3$ **C** $2\,m^3$ **D** $8 \times 10^{7}\,m^3$

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173. 9701_s20_qp_11 Q: 9

A sample of argon gas has a mass of 0.20 g, at a pressure of 100 000 Pa and a temperature of 12 °C.

Which volume does the gas occupy?

A $1.2 \times 10^{-4}\,cm^3$

B $5.0\,cm^3$

C $59\,cm^3$

D $119\,cm^3$

---

174. 9701_s20_qp_12 Q: 9

The complete combustion of 2 moles of an alkane produces 400 dm^3 of carbon dioxide measured at 301 K and 1×10^5 Pa. Carbon dioxide can be assumed to behave as an ideal gas under these conditions.

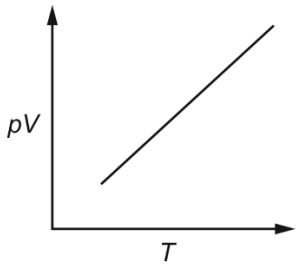
What is the formula of the alkane?

A C_8H_{18} **B** $C_{16}H_{34}$ **C** $C_{20}H_{42}$ **D** $C_{40}H_{82}$

---

175. 9701_w20_qp_12 Q: 6

A graph of pV against T is shown for a fixed mass of gas. (p = pressure, V = volume and T = temperature in K.)



Which gas gives this graph over the widest range of temperatures and pressures?

A hydrogen, H_2

B hydrogen chloride, HCl

C hydrogen fluoride, HF

D oxygen, O_2

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176. 9701_w20_qp_12 Q: 7

A weather balloon is filled with 12.0 kg helium. The weather balloon reaches a height of 20 km, the pressure inside the balloon is 6000 Pa and the temperature is 216 K.

What is the volume of the weather balloon at this height, correct to three significant figures?

A 897 dm^3 **B** 1790 dm^3 **C** 897 000 dm^3 **D** 1 790 000 dm^3

---

177. 9701_m19_qp_12 Q: 6

A sample of gas occupies 240 cm^3 at 37 °C and 100 kPa.

How many moles of gas are present in the sample?

A 9.32×10^{-6} **B** 9.32×10^{-3} **C** 0.0781 **D** 78.1

---

178. 9701_s19_qp_11 Q: 7

Under which conditions will nitrogen behave most like an ideal gas?

	temperature	pressure
A	low	high
B	high	low
C	low	low
D	high	high

---

179. 9701_s19_qp_11 Q: 12

1.15 g of a metallic element needs 300 cm^3 of oxygen for complete reaction, under room conditions, to form an oxide which contains O^{2-} ions.

What could be the identity of this metallic element?

A calcium

B magnesium

C potassium

D sodium

---

180. 9701_s19_qp_12 Q: 6

X, Y and Z are all gases that behave ideally and react according to the equation shown.

$$X(g) + 2Y(g) \rightarrow 2Z(g)$$

When 3.0 mol of X and 3.0 mol of Y are placed inside a container with a volume of 1.0 dm^3, they react to form the maximum amount of Z.

The final temperature of the reaction vessel is 120 °C.

What is the final pressure inside the reaction vessel?

A 4.49×10^6 Pa

B 9.80×10^6 Pa

C 1.47×10^7 Pa

D 1.96×10^7 Pa

---

181. 9701_s19_qp_13 Q: 7

What changes in conditions or molecular properties make it more likely that gases approach ideal behaviour?

A higher pressure

B lower temperature

C more polar molecules

D weaker intermolecular forces

---

182. 9701_w19_qp_12 Q: 5

In this question you should assume the vapour behaves as an ideal gas.

0.175 g of a volatile liquid produces a vapour of volume 4.50×10^{-5} m^3 at 100 °C and pressure of 1.013×10^5 Pa.

What is the M_r of the liquid?

A 31.9 **B** 87.1 **C** 119 **D** 127

---

183. 9701_m18_qp_12 Q: 7

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

$$pV = nRT$$

0.960 g of oxygen gas is contained in a vessel of volume 7.00×10^{-3} m^3 at a temperature of 30 °C.

Assume that the gas behaves as an ideal gas.

What is the pressure in the vessel?

A 1.07 kPa **B** 2.14 kPa **C** 10.8 kPa **D** 21.6 kPa

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184. 9701_s18_qp_12 Q: 6

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

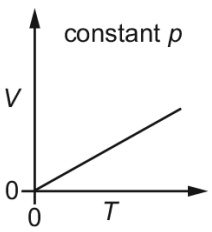
A HC*l* **B** He **C** CH_4 **D** N_2

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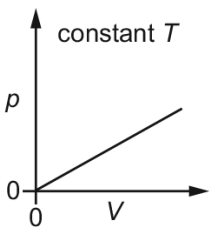
185. 9701_s18_qp_13 Q: 6

Which diagram correctly describes the behaviour of a fixed mass of an ideal gas? (T is measured in K.)

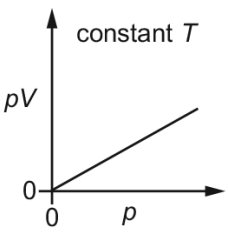
A



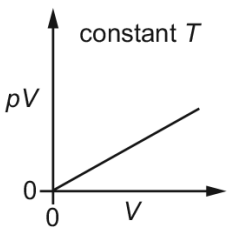
B



C



D



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186. 9701_w18_qp_11 Q: 2

What is a basic assumption of the kinetic theory, as applied to an ideal gas?

A Collisions between gas molecules are elastic.

B Each gas molecule occupies a finite volume.

C Gases consist of particles that experience the force of gravity.

D Gas molecules attract each other with weak intermolecular forces.

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187. 9701_w18_qp_11 Q: 5

In this question you should assume methane behaves as an ideal gas.

The gas laws can be summarised in the ideal gas equation below.

$$pV = nRT$$

The volume of a sample of methane is measured at a temperature of 60 °C and a pressure of 103 kPa. The volume measured is 5.37×10^{-3} m^3.

What is the mass of the sample of methane, given to two significant figures?

A 0.0032 g **B** 0.018 g **C** 3.2 g **D** 18 g

---

188. 9701_w18_qp_12 Q: 6

Exactly 1.00 g of a metallic element reacts completely with 300 cm^3 of oxygen at 298 K and 1 atm pressure to form an oxide which contains O^{2-} ions.

The volume of one mole of gas at this temperature and pressure is 24.0 dm^3.

What could be the identity of the metal?

A calcium

B magnesium

C potassium

D sodium

---

189. 9701_m17_qp_12 Q: 6

Which gas sample contains the **fewest** molecules?

A 1.00 dm^3 of carbon dioxide at 27 °C and 2.0 kPa

B 1.00 dm^3 of hydrogen at 100 °C and 2.0 kPa

C 1.00 dm^3 of nitrogen at 300 °C and 4.0 kPa

D 1.00 dm^3 of oxygen at 250 °C and 3.0 kPa

---

190. 9701_s17_qp_12 Q: 5

At a temperature of 2500 K and a pressure of 1.00×10^{-4} Pa a sample of 0.321 g of sulfur vapour has a volume of 2.08×10^{6} m^3.

What is the molecular formula of sulfur under these conditions?

A S **B** S_2 **C** S_4 **D** S_8

---

191. 9701_s17_qp_13 Q: 5

All gases listed are at the same pressure.

Which gas will most closely approach ideal behaviour?

A ammonia at 100 K

B ammonia at 500 K

C neon at 100 K

D neon at 500 K

---

192. 9701_w17_qp_11 Q: 5

A fluorescent light tube has an internal volume of 400 cm^3 and an internal pressure of 200 kPa.

It is filled with 0.03 moles of an ideal gas.

What is the temperature of the gas inside the fluorescent light tube?

A 3.21×10^{-1} K

B 3.21×10^{2} K

C 3.21×10^{5} K

D 3.21×10^{8} K

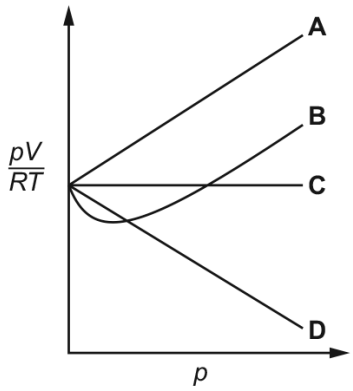
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193. 9701_w17_qp_12 Q: 5

A sample of an ideal gas is contained at a constant temperature of 300 K in a gas syringe.

The pressure is increased and a graph of $\frac{pV}{RT}$ against pressure is plotted.

Which graph correctly represents the results?



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194. 9701_m16_qp_12 Q: 7

What is the volume of steam produced when 1.00 g of ice is heated to 323 °C at a pressure of 101 kPa?

A 0.27 dm^3 **B** 1.3 dm^3 **C** 2.7 dm^3 **D** 48 dm^3

---

195. 9701_s16_qp_12 Q: 6

Argon is a gas used to fill electric light bulbs.

Under which conditions of pressure and temperature will argon behave most like an ideal gas?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

---

196. 9701_s16_qp_12 Q: 7

0.10 g of the volatile liquid X formed 0.025 dm^3 of vapour at 100 °C and atmospheric pressure.

1 mol of vapour occupies 22.4 dm^3 at 0 °C and atmospheric pressure.

What is the relative molecular mass of X?

A $\frac{0.025 \times 273 \times 22.4}{0.10 \times 373}$

B $\frac{0.025 \times 373 \times 22.4}{0.10 \times 273}$

C $\frac{0.10 \times 273 \times 22.4}{0.025 \times 373}$

D $\frac{0.10 \times 373 \times 22.4}{0.025 \times 273}$

---

197. 9701_s16_qp_13 Q: 2

What will make it more likely that a gas will approach ideal behaviour?

A higher pressure

B lower temperature

C more polar molecules

D weaker intermolecular forces

---

198. 9701_w16_qp_11 Q: 2

In the ideal gas equation, $pV = nRT$, what are the units of n and T?

	n	T
A	no units	°C
B	no units	K
C	mol	°C
D	mol	K

---

199. 9701_w16_qp_11 Q: 7

The approximate percentage composition of the atmospheres on four different planets is given in the table below.

Which mixture of gases has the greatest density?

	planet	major gases / % by number of molecules		
		H_2	He	CH_4
A	Jupiter	89.8	10.2	0.0
B	Neptune	80.0	19.0	1.0
C	Saturn	96.3	3.3	0.4
D	Uranus	82.5	15.2	2.3

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200. 9701_w16_qp_12 Q: 8

In an experiment, a sample of a pure gas is put into a gas syringe at a temperature of 300 K and pressure of 16 kPa. The gas is compressed until the volume occupied by the gas is halved.

After compression, the temperature of the gas in the syringe is 375 K and the pressure is 40 kPa.

Which statement is correct?

A Intermolecular forces between the gas molecules are significant.

B It is possible to calculate the number of moles of gas present using these data alone.

C The gas is behaving ideally.

D The pressures used are too high for ideal gas behaviour.

---

201. 9701_s15_qp_11 Q: 3

Use of the Data Booklet is relevant to this question.

1.00 g of carbon is combusted in a limited supply of pure oxygen. 0.50 g of the carbon combusts to form CO_2 and 0.50 g of the carbon combusts to form CO.

The resultant mixture of CO_2 and CO is passed through excess NaOH(aq) and the remaining gas is then dried and collected.

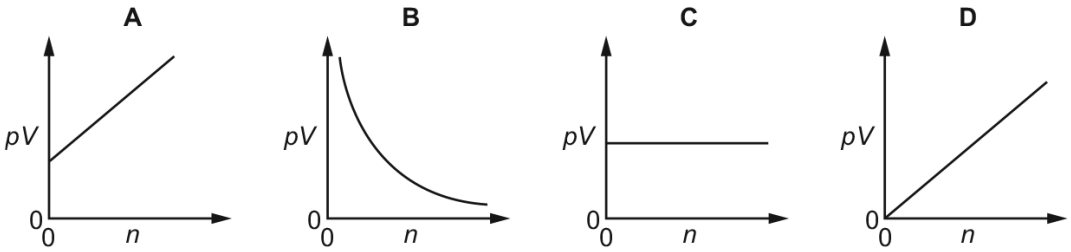
What is the volume of the remaining gas? (All gas volumes are measured at 25 °C and 1 atmosphere pressure.)

A 1 dm^3 **B** 1.5 dm^3 **C** 2 dm^3 **D** 3 dm^3

---

202. 9701_s15_qp_13 Q: 2

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



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203. 9701_s15_qp_13 Q: 11

Use of the Data Booklet is relevant to this question.

The gas laws can be summarised in the ideal gas equation below.

$$pV = nRT$$

When an evacuated tube of volume 400 cm^3 is filled with gas at 300 K and 101 kPa, the mass of the tube increases by 0.65 g.

Assume the gas behaves as an ideal gas.

What could be the identity of the gas?

A argon

B helium

C krypton

D neon

---

204. 9701_w15_qp_12 Q: 19

Use of the Data Booklet is relevant to this question.

4.70 g of an ammonium salt is heated with excess aqueous sodium hydroxide. The volume of ammonia gas given off, measured at room temperature and pressure, is 1.41 dm^3.

Which ammonium salt was used?

A ammonium bromide (M_r = 97.9)

B ammonium carbonate (M_r = 96)

C ammonium nitrate (M_r = 80)

D ammonium sulfate (M_r = 132.1)

4.2 Bonding and structure

205. 9701_m22_qp_12 Q: 7

Elements X, Y and Z are all in the first two periods of the Periodic Table.

Their Pauling electronegativity values, E_N, are shown.

element	E_N
X	1.0
Y	2.1
Z	4.0

Substances exist with formulae XZ, YZ and Z_2.

Which row puts these substances in order of increasing melting point?

	lowest melting point	→	highest melting point
A	XZ	YZ	Z_2
B	XZ	Z_2	YZ
C	Z_2	YZ	XZ
D	Z_2	XZ	YZ

---

206. 9701_s21_qp_12 Q: 6

Sodium chloride, water and air represent three states of matter – solid, liquid and gas.

Which row is correct?

	sodium chloride	water	air
A	particles held in rigid structure	can easily be compressed	can easily be compressed
B	particles stationary	particles move	cannot easily be compressed
C	particles stationary	particles stationary	particles move
D	resistant to change of shape	cannot easily be compressed	can easily be compressed

---

207. 9701_s20_qp_11 Q: 19

What is the order of increasing melting point of the three chlorides shown?

CCl_4 $MgCl_2$ PCl_5

	lowest melting point	→	highest melting point
A	CCl_4	PCl_5	$MgCl_2$
B	$MgCl_2$	CCl_4	PCl_5
C	$MgCl_2$	PCl_5	CCl_4
D	PCl_5	CCl_4	$MgCl_2$

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208. 9701_s20_qp_12 Q: 1

In which carbon allotrope are all electrons localised?

A buckminsterfullerene

B diamond

C graphite

D graphene

---

209. 9701_s20_qp_13 Q: 3

Solid carbon dioxide, CO_2, is similar to solid iodine, I_2, in its structure.

Which statement about solid CO_2 and solid SiO_2 is correct?

A Both solid CO_2 and solid SiO_2 exist in a lattice structure.

B Both solid CO_2 and solid SiO_2 have a simple molecular structure.

C Both solid CO_2 and solid SiO_2 have atoms joined by single covalent bonds.

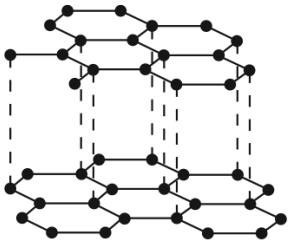
D Both solid CO_2 and solid SiO_2 change spontaneously to gas at s.t.p..

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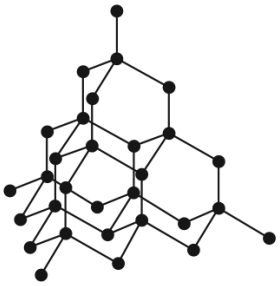
210. 9701_m19_qp_12 Q: 7

P, Q and R represent three different structures of an element.

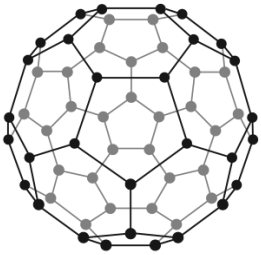
P



Q



R



Which structures are giant molecular?

A P, Q and R

B P and Q only

C P and R only

D Q and R only

---

211. 9701_s19_qp_12 Q: 5

The table shows some properties of four substances.

Which substance could be potassium iodide?

	melting point of solid / °C	electrical conductivity when molten
A	–66	poor
B	–39	good
C	680	good
D	1600	poor

---

212. 9701_s19_qp_12 Q: 7

Which pair of substances are both simple molecular?

A C_{60} and graphene

B C_{60} and iodine

C graphene and graphite

D graphite and iodine

---

213. 9701_s19_qp_13 Q: 4

Element W is in period three of the Periodic Table and has a solid, white oxide, X. X is thermally stable and has a very high melting point.

X is slightly soluble in water.

Which row describes the structure and bonding of X?

	structure	bonding
A	giant three dimensional lattice	covalent
B	strong double bonds within small molecules	covalent
C	giant three dimensional lattice	ionic
D	strong ionic bonds within small molecules	ionic

---

214. 9701_s19_qp_13 Q: 5

Ethane, CH_3CH_3, and fluoromethane, CH_3F, have the same number of electrons in their molecules.

Their boiling points are given.

CH_3CH_3	184.5 K
CH_3F	194.7 K

What is responsible for this difference in boiling points?

A CH_3F has a larger M_r than CH_3CH_3.

B CH_3F has a permanent dipole, CH_3CH_3 does not.

C CH_3F has a strong C–F bond, CH_3CH_3 does not.

D Hydrogen bonding occurs in CH_3F, but not in CH_3CH_3.

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215. 9701_s18_qp_11 Q: 6

Which solid contains more than one type of bonding?

A iodine

B silicon dioxide

C sodium chloride

D zinc

---

216. 9701_s18_qp_12 Q: 3

In which pair does the second substance have a **lower** boiling point than the first substance?

A C_2H_6 and C_2H_5Cl

B CH_3OCH_3 and C_2H_5OH

C Ne and Ar

D CH_3NH_2 and C_2H_6

---

217. 9701_s18_qp_12 Q: 9

Materials can be classified by their chemical structures. Four common types of structure are metallic, ionic, simple molecular and giant molecular.

Some physical properties of four substances are shown in the table.

Which substance has a simple molecular structure?

	melting point / °C	effect of adding water	electrical conductivity
A	64	reacts	good when solid
B	113	insoluble	always poor
C	767	soluble	good when solid
D	1600	insoluble	always poor

---

218. 9701_s18_qp_13 Q: 1

Why is the boiling point of ammonia, NH_3, higher than the boiling point of phosphine, PH_3?

A Ammonia molecules are polar; phosphine molecules are not.

B Ammonia molecules have significant hydrogen bonding; phosphine molecules do not.

C N–H covalent bonds are stronger than P–H covalent bonds.

D There is one lone pair in each ammonia molecule but no lone pair in each phosphine molecule.

---

219. 9701_w18_qp_11 Q: 14

Which row describes the structure and bonding of SiO_2 and $SiCl_4$?

	SiO_2		$SiCl_4$	
	bonding	structure	bonding	structure
A	covalent	giant	covalent	giant
B	covalent	giant	covalent	simple
C	ionic	giant	covalent	giant
D	ionic	giant	covalent	simple

---

220. 9701_m17_qp_12 Q: 4

The boiling points of methane, ethane, propane and butane are given.

compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3CH_2CH_2CH_3$
boiling point/K	112	185	231	273

Which statement explains the increase in boiling point from methane to butane?

A Closer packing of molecules results in stronger van der Waals' forces.

B More covalent bonds are present and therefore more energy is required to break the bonds.

C More electrons in the molecules results in stronger van der Waals' forces.

D More hydrogen atoms in the molecules results in stronger hydrogen bonding.

---

221. 9701_w17_qp_11 Q: 4

In the sodium chloride lattice the number of chloride ions that surround each sodium ion is called the *co-ordination number* of the sodium ions.

What are the co-ordination numbers of the sodium ions and the chloride ions in the sodium chloride lattice?

	sodium ions	chloride ions
A	4	6
B	6	4
C	6	6
D	8	6

---

222. 9701_m16_qp_12 Q: 8

Solid carbon dioxide, CO_2, is similar to solid iodine, I_2, in its structure and properties. Carbon is in Group 14. Silica, SiO_2, is a Group 14 compound.

Which statement about solid CO_2 and solid SiO_2 is correct?

A Both solids exist in a lattice structure.

B Both solids have a simple molecular structure.

C Both solids have atoms joined by single covalent bonds.

D Both solids change spontaneously to gas at s.t.p.

---

223. 9701_m16_qp_12 Q: 9

An article in a science magazine contains the following statement.

'It is lighter than a feather, stronger than steel, yet incredibly flexible and more conductive than copper.'

Which form of carbon is being described?

A buckminsterfullerene

B diamond

C graphene

D graphite

---

224. 9701_s15_qp_12 Q: 4

Which solid has a simple molecular lattice?

A calcium fluoride

B nickel

C silicon(IV) oxide

D sulfur

---

225. 9701_s15_qp_13 Q: 14

The compound $(CH_3)_3NAlCl_3$ has a simple molecular structure.

Which statement about $(CH_3)_3NAlCl_3$ is correct?

A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.

B The Al atom has an incomplete valance shell of electrons.

C The bonds around the Al atom are planar.

D The molecules contain coordinate and covalent bonding

---

226. 9701_w15_qp_11 Q: 5

Some car paints contain small flakes of silica, SiO_2.

In the structure of solid SiO_2

- each silicon atom is bonded to **x** oxygen atoms,
- each oxygen atom is bonded to **y** silicon atoms,
- each bond is a **z** type bond.

What is the correct combination of **x**, **y** and **z** in these statements?

	x	y	z
A	2	1	covalent
B	2	1	ionic
C	4	2	covalent
D	4	2	ionic

---

227. 9701_w15_qp_12 Q: 3

Three substances have the physical properties shown in the table.

substance	melting point /°C	boiling point /°C	conductivity (solid)	conductivity (liquid)	conductivity (aqueous)
U	420	907	good	good	insoluble
V	993	1695	poor	good	good
W	–70	58	poor	poor	hydrolyses, resulting solution conducts well

What could be the identities of **U**, **V** and **W**?

	U	V	W
A	Na	KCl	$SiCl_4$
B	Na	NaF	C_2H_5Br
C	Zn	KCl	HCl
D	Zn	NaF	$SiCl_4$

Chapter 4

States of matter

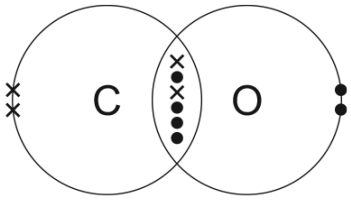
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4.1 The gaseous state: ideal and real gases and pV = nRT

17. 9701_s21_qp_21 Q: 2

Carbon monoxide gas, CO(g), and nitrogen gas, N_2(g), are both diatomic molecules.

(a) The diagram shows the arrangement of outer electrons in a molecule of CO(g).



(i) State **one** similarity and **one** difference in the way the atoms in a carbon monoxide molecule are bonded together compared to the atoms in a nitrogen molecule.

.....

.....

..... [2]

(ii) The table states the electronegativity values of carbon, nitrogen and oxygen atoms.

	C	N	O
electronegativity	2.5	3.0	3.5

Use the electronegativity values and relevant details from the *Data Booklet* to complete the table below.

	N_2	CO
number of electrons per molecule		
type(s) of intermolecular (van der Waals') force		

[2]

(b) N_2(g) is less reactive than CO(g) even though N_2(g) has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than N_2(g).

.....

..... [1]

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

..... [1]

(ii) Explain why $N_2(g)$ behaves more like an ideal gas than CO(g) does at 20.0 °C and 101 kPa.

.....

.....

..... [2]

(d) Calculate the amount, in mol, of pure nitrogen gas which occupies 100 cm^3 at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol
[3]

[Total: 11]

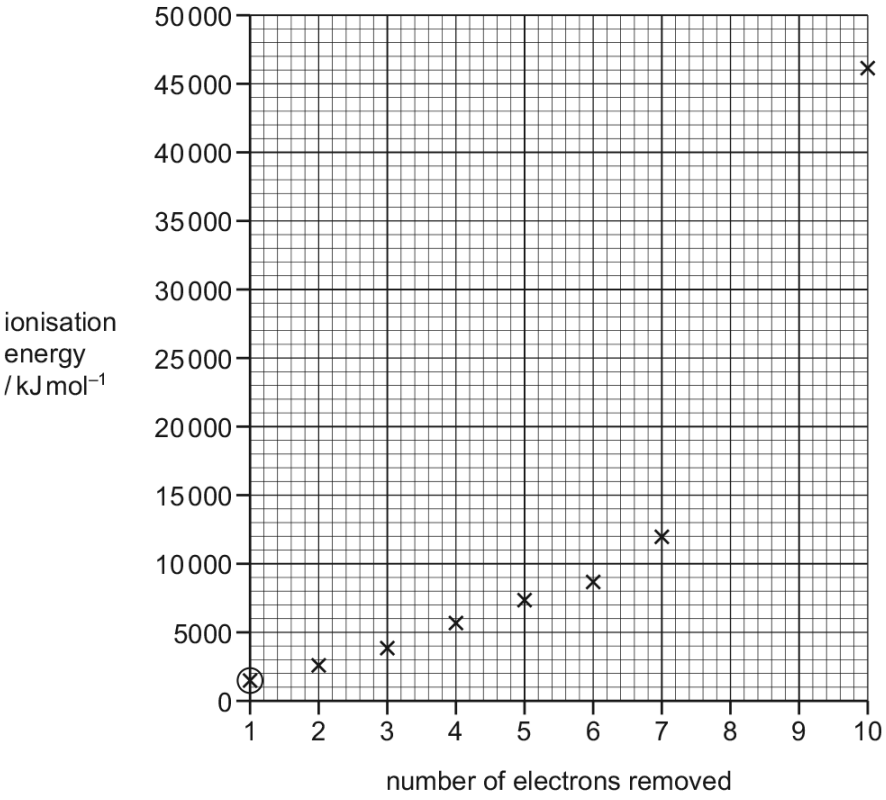
18. 9701_s19_qp_21 Q: 3

(a) Construct an equation for the **second** ionisation energy of argon.

..... [1]

(b) The graph shows successive ionisation energies for the element argon.

Complete the graph with predictions for the eighth and ninth ionisation energies of argon. Use a cross (×) for each data point. [2]



(c) The energy value required to remove the first electron from an atom of argon is circled on the graph.

Sketch the shape of the orbital that contains this electron.

[1]

(d) Chlorine exists as a diatomic gas, Cl_2(g). A sample of Cl_2(g) was made during a chemical reaction. When measured at 404 kPa and 25 °C the sample occupied a volume of 20.0 cm^3.

(i) Calculate the mass, in grams, of Cl_2(g) formed.

For this calculation, assume that chlorine behaves as an ideal gas under these conditions.

mass of Cl_2(g) = ... g [3]

(ii) Calculate the number of chlorine atoms in this sample of Cl_2(g). You may find it helpful to use your answer to **(d)(i)**.

If you are unable to calculate an answer to **(d)(i)**, use 0.36 g of Cl_2. This is **not** the correct answer.

number of chlorine atoms = ... [2]

(iii) Cl_2(g) does **not** behave as an ideal gas under these conditions.

Explain why Cl_2(g) behaves even **less** ideally at:

- very high pressures

.....

.....

.....

- very low temperatures.

.....

.....

.....

[2]

[Total: 11]

4.2 The solid state: lattice structures

19. 9701_s21_qp_22 Q: 2

The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S, is a crystalline solid with a melting point of 938 °C. It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

..... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....

..... [2]

(b) Carbon monoxide, CO, is a gas at room temperature and pressure. It contains a coordinate bond.

(i) Explain what is meant by *coordinate bond*.

.....

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in CO.

Show the electrons belonging to the C atom as ×.

Show the electrons belonging to the O atom as ●.

[2]

Nitrogen, N_2, is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

.....

.....

.....

..... [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of $N_2(g)$ and CO(g).

	$N_2(g)$	CO(g)
number of electrons per molecule	14	14
presence of a dipole moment	✗	✓
boiling point/°C	–195.8	–191.5
intermolecular forces (van der Waals')		

[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

..... [1]

[Total: 13]

Q1.

2 The unsaturated hydrocarbon ethyne (acetylene), C_2H_2, is widely used in 'oxy-acetylene torches' for cutting and welding metals. In the torch, ethyne is burned in oxygen to produce a flame with a temperature of 3400 K.

(a) Ethyne is a linear molecule with a triple bond, C≡C, between the two carbon atoms.

Draw a 'dot-and-cross' diagram of an ethyne molecule.

[1]

(b) When used for cutting or welding, ethyne is transported in cylinders which contain the gas under pressure. A typical cylinder has a volume of 76 dm^3 and contains ethyne gas at 1515 kPa pressure at a temperature of 25 °C.

Use the general gas equation, $pV = nRT$, to calculate the amount, in moles, of ethyne in this cylinder.

[2]

(c) In some countries, ethyne is manufactured from calcium carbide, CaC_2, which is produced by heating quicklime and coke together at 2300 K.

$$CaO + 3C \longrightarrow CaC_2 + CO$$

When water is added to the CaC_2, calcium hydroxide, $Ca(OH)_2$, and ethyne, C_2H_2, are produced.

(i) Construct a balanced equation for the formation of ethyne from calcium carbide.

.....

(ii) Use this equation and your answer to part **(b)** to calculate the mass of CaC_2 which will react with an excess of water to produce enough ethyne to fill 100 cylinders of the gas.

[3]

Q2 .

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) .....

.....

(ii) .....

.....

[2]

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

(i) .....

(ii) .....

[2]

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

ammonia, neon, nitrogen

most ideal ..... **least ideal**

Explain your answer.

.....

.....

[3]

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

.....

.....

.....

.....[2]

Q3.

Bicycles may be carried on commercial airliners. When carried on airliners, bicycles are placed in the luggage hold. This is a part of the aircraft which, in flight, will have different temperatures and air pressures from those at sea level.

This question concerns the change in pressure in an inflated bicycle tyre from when it is at sea level to when it is in the hold of an airliner in flight.

(d) At sea level and a temperature of 20 °C an inflated bicycle tyre contains 710 cm^3 of air at an internal pressure of 6×10^5 Pa.

Use the general gas equation $PV = nRT$ to calculate the amount, in moles, of air in the tyre at sea level.

[2]

The same bicycle, with its tyres inflated at sea level as described in **(d)** above, is placed in the luggage hold of an airliner. At a height of 10 000 m, the temperature in the luggage hold is 5 °C and the air pressure is 2.8×10^4 Pa.

(e) Assuming the volume of the tyre does not change, use your answer to **(d)** to calculate the pressure inside the tyre at a height of 10 000 m.

[2]

Q4.

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

.....

.....

.....

.....

.....

.....

(ii) Suggest **one** reason why CO_2 does not behave as an ideal gas.

.....

[5]

1.
Why does copper wire conduct electricity when a potential difference is applied?

A Bonding electrons in the crystal lattice move.

B Copper(II) ions move to the cathode.

C The atoms of copper become ionised.

D The crystal lattice breaks down.

[2002 M/J (5)]

2.
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.

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

A $1\frac{1}{3}$ kPa **B** $1\frac{1}{2}$ kPa **C** $1\frac{2}{3}$ kPa **D** 2 kPa

[2002 M/J (6)]

3.
When heated, solid iodine readily forms iodine vapour.

What does this information suggest about the nature of the particles in these two physical states of iodine?

	solid	*vapour*
A	ionic	atomic
B	ionic	molecular
C	molecular	atomic
D	molecular	molecular

[2002 M/J (7)]

4.
Which of the following exists in the solid state as a giant covalent lattice?

A ice

B iodine

C silicon(IV) oxide

D tin(IV) chloride

[2002 O/N (7)]

5.
A 2 g sample of hydrogen at temperature T and of volume V exerts a pressure p. Deuterium, $^{2}_{1}H$, is an isotope of hydrogen.

Which of the following would also exert a pressure p at the same temperature T?

A 2 g of deuterium of volume V

B 4 g of deuterium of volume $\frac{V}{2}$

C a mixture of 1 g of hydrogen and 2 g of deuterium of total volume V

D a mixture of 2 g of hydrogen and 1 g of deuterium of total volume $2V$

[2002 O/N (8)]

6.
Which of the following are features of the structure of metallic copper?

1 ionic bonds

2 delocalised electrons

3 lattice of ions

[2002 O/N (32)]

7.
Which of the following solids has a simple molecular lattice?

A magnesium oxide

B sodium

C silicon(IV) oxide

D sulphur

[2003 M/J (5)]

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8.

Measured values of the pressure, volume and temperature of a known mass of a gaseous compound are to be substituted into the equation

$$pV = nRT$$

in order to calculate the relative molecular mass, M_r, of the compound.

Which conditions of pressure and temperature would give the most accurate value of M_r?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

[2003 M/J (6)]

9.

A substance commonly found in the house or garden has the following properties.

- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

A brass

B paper

C poly(ethene)

D silicon(IV) oxide

[2003 O/N (8)]

10.

Use of the Data Booklet is relevant to this question.

In an experiment using a gas syringe, 0.10 g of a gas is found to occupy 83.1 cm^3, measured at standard pressure (1.0×10^5 Pa) and 27 °C.

What is the relative molecular mass of the gas?

A $\dfrac{0.10 \times 8.31 \times 27}{1.0 \times 10^5 \times 83.1}$

B $\dfrac{0.10 \times 8.31 \times 300}{1.0 \times 10^5 \times 83.1}$

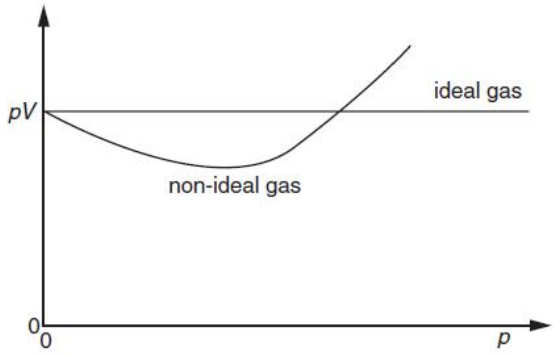
C $\dfrac{0.10 \times 8.31 \times 27}{1.0 \times 10^5 \times 83.1 \times 10^{-6}}$

D $\dfrac{0.10 \times 8.31 \times 300}{1.0 \times 10^5 \times 83.1 \times 10^{-6}}$

[2003 O/N (9)]

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

B ethene

C methane

D nitrogen

[2003 O/N (10)]

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12.
Which pairs of compounds contain one that is giant ionic and one that is simple molecular?

1 Al_2O_3 and Al_2Cl_6

2 SiO_2 and $SiCl_4$

3 P_4O_{10} and PCl_3

[2004 M/J (34)]

13.
Use of the Data Booklet is relevant to this question.

Which expression gives the pressure exerted by 1.6×10^{-3} mol of N_2 in a container of volume $3.0\,dm^3$ at 273 °C?

A $\dfrac{1.6 \times 10^{-3} \times 8.31 \times 273}{3.0 \times 10^{-6}}$ Pa

B $\dfrac{1.6 \times 10^{-3} \times 8.31 \times (273 + 273)}{3.0 \times 10^{-6}}$ Pa

C $\dfrac{1.6 \times 10^{-3} \times 8.31 \times 273}{3.0 \times 10^{-3}}$ Pa

D $\dfrac{1.6 \times 10^{-3} \times 8.31 \times (273 + 273)}{3.0 \times 10^{-3}}$ Pa

[2004 O/N (8)]

14.
Three substances, *R*, *S*, *T*, have physical properties as shown.

substance	mp/°C	bp/°C	electrical conductivity	
			of solid	of liquid
R	801	1413	poor	good
S	2852	3600	poor	good
T	3550	4827	good	not known

What could be the identities of *R*, *S* and *T*?

	R	*S*	*T*
A	NaF	KCl	Cu
B	NaBr	BaO	SiO_2
C	NaCl	MgO	C [graphite]
D	NaBr	CaO	C [diamond]

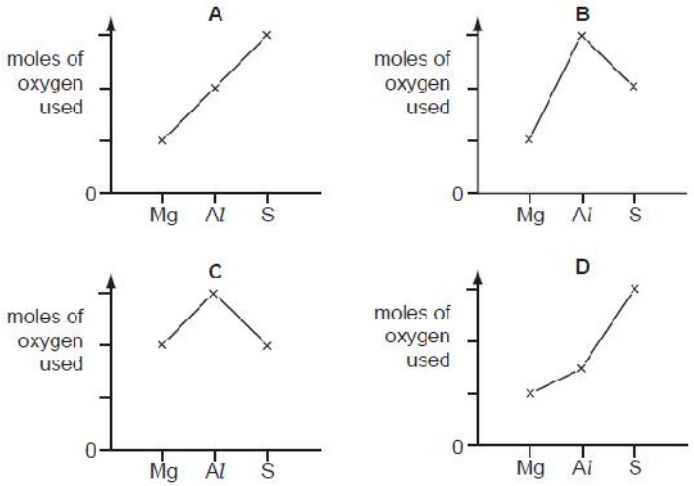
[2005 M/J (6)]

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15.

One mole of magnesium, aluminium and sulphur are each completely burned in an excess of oxygen gas.

Which graph shows the moles of oxygen used in each case?



[2005 O/N (12)]

16.

Which of the following least resembles an ideal gas?

A ammonia

B helium

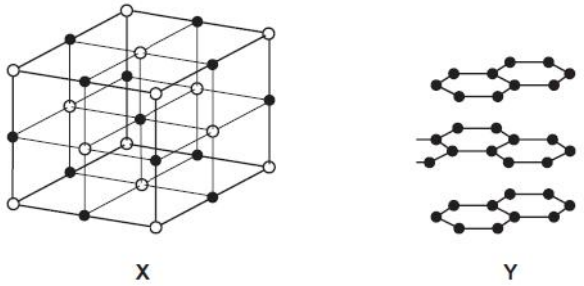
C hydrogen

D trichloromethane

[2006 M/J (6)]

17.

The diagram shows part of the lattice structures of solids **X** and **Y**. [In **X**, ○ and ● represent particles of different elements.]



What are the types of bonding present in **X** and **Y**?

	X	Y
A	covalent	metallic
B	ionic	covalent
C	ionic	metallic
D	metallic	ionic

[2006 M/J (7)]

18.

Compound **X**

- does not conduct electricity when in a liquid state,
- when added to water produces a solution that readily conducts electricity.

What could **X** be?

1 $MgCl_2$

2 $SiCl_4$

3 PCl_3

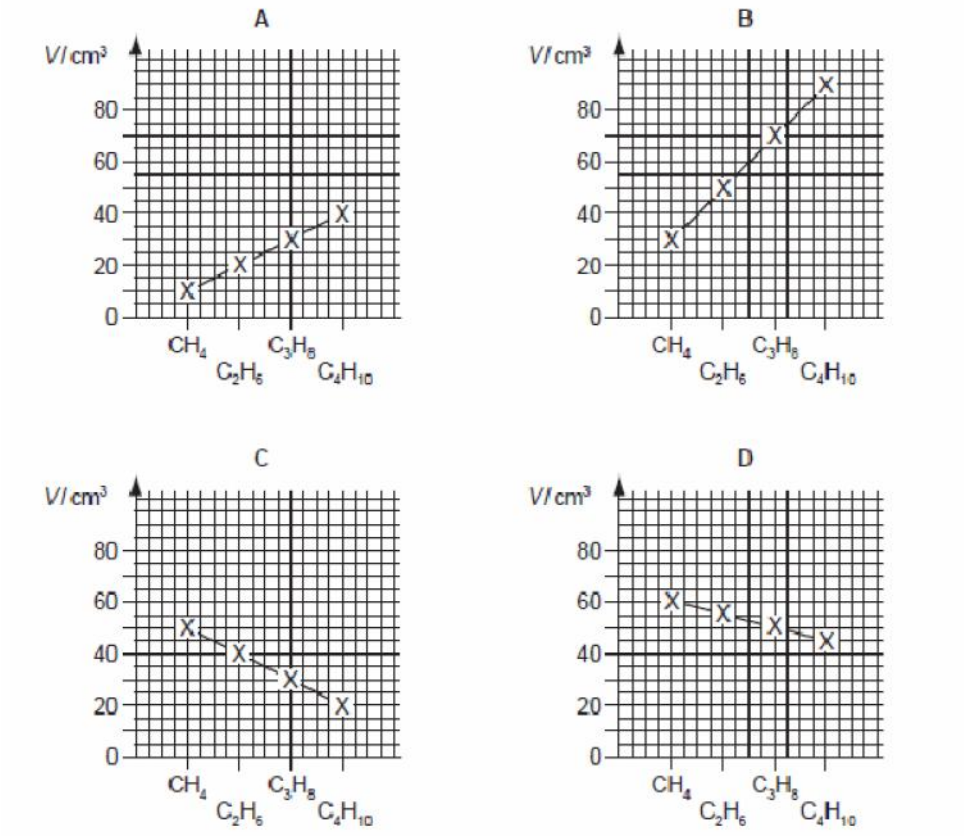
[2006 M/J (34)]

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19.

Samples of 10 cm^3 of each of the first four members of the alkane series are separately mixed with 70 cm^3 of oxygen. Each is then burned and the total volume, *V*, of residual gas measured again at room temperature and pressure.

Which graph represents the results that would be obtained?

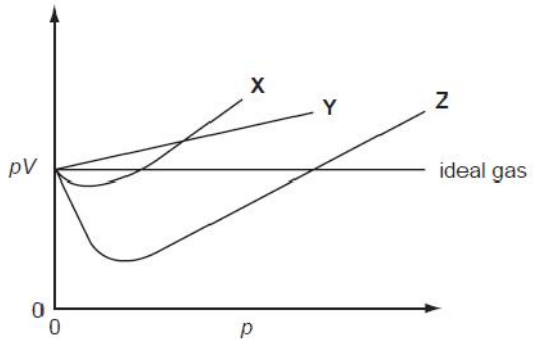


[2006 O/N (4)]

20.

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

[2006 O/N (6)]

21.

What are the lattice structures of solid diamond, iodine and silicon(IV) oxide?

	giant molecular	simple molecular
A	diamond, silicon(IV) oxide	iodine
B	diamond, iodine	silicon(IV) oxide
C	iodine	diamond, silicon(IV) oxide
D	silicon(IV) oxide	diamond, iodine

[2007 O/N (7)]

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22.
What are assumptions of the kinetic theory of gases and hence of the ideal gas equation, $PV = nRT$?

1 Molecules move without interacting with one another except for collisions.

2 Intermolecular forces are negligible.

3 Intermolecular distances are much greater than the molecular size.

[2007 O/N (31)]

23.
The density of ice is 1.00 g cm^{-3}.

What is the volume of steam produced when 1.00 cm^3 of ice is heated to 323 °C (596 K) at a pressure of one atmosphere (101 kPa)?

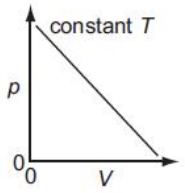
[1 mol of a gas occupies 24.0 dm^3 at 25 °C (298 K) and one atmosphere.]

A 0.267 dm^3 **B** 1.33 dm^3 **C** 2.67 dm^3 **D** 48.0 dm^3

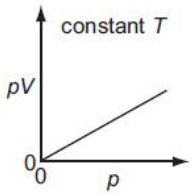
[2008 M/J (6)]

24.
Which diagram correctly describes the behaviour of a fixed mass of an ideal gas? (T is measured in K.)

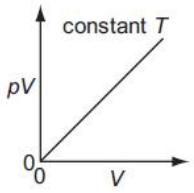
A



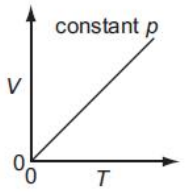
B



C



D



[2008 M/J (8)]

25.
A substance commonly found in the house or garden has the following properties.

- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

A brass

B paper

C poly(ethene)

D silicon(IV) oxide

[2008 O/N (6)]

26.
Which of the following would behave most like an ideal gas at room temperature?

A carbon dioxide

B helium

C hydrogen

D nitrogen

[2008 O/N (7)]

27.
An ideal gas obeys the gas laws under all conditions of temperature and pressure.

Which of the following are true for an ideal gas?

1 The molecules have negligible volume.

2 There are no forces of attraction between molecules.

3 The molecules have an average kinetic energy which is proportional to its absolute temperature.

[2009 M/J (31)]

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28.

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

A ammonia

B carbon dioxide

C helium

D oxygen

[2010 M/J-11 (3)]

29.

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

B 5.6 g N_2 gas

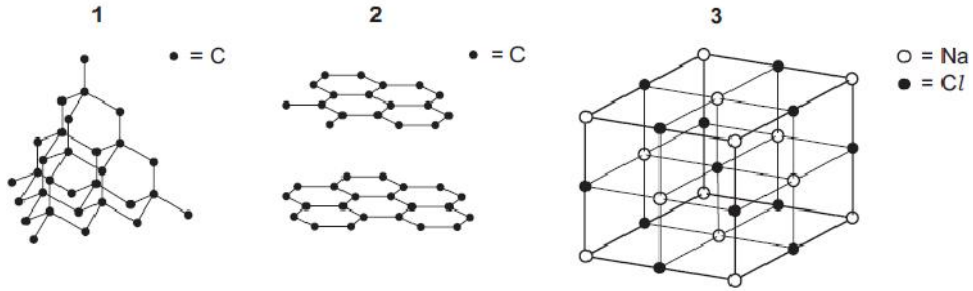
C 8.0 g SO_2 gas

D 11.0 g CO_2 gas

[2010 M/J-11 (9)]

30.

Which diagrams represent part of a giant molecular structure?



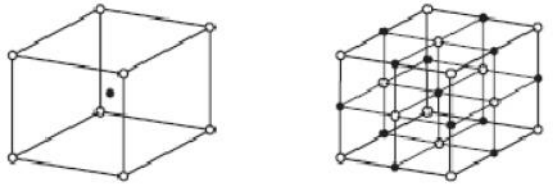
[2010 M/J-11 (31)]

31.

The table gives the radii, in pm, of some ions. [1 pm = 10^{-12} m]

ion	radii
Na^+	102
Mg^{2+}	72
Cs^+	167
Cl^-	181
O^{2-}	140

Caesium chloride, CsCl, has a different lattice structure from both sodium chloride, NaCl, and magnesium oxide, MgO.



CsCl lattice NaCl and MgO lattice

Which factor appears to determine the type of lattice for these three compounds?

A the charge on the cation

B the ratio of the ionic charges

C the ratio of the ionic radii

D the sum of the ionic charges

[2010 O/N-12 (3)]

32.

Which solid has a simple molecular lattice?

A calcium fluoride

B nickel

C silicon(IV) oxide

D sulfur

[2010 O/N-12 (5)]

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33.

Flask X contains 5 dm^3 of helium at 12 kPa pressure and flask Y contains 10 dm^3 of neon at 6 kPa pressure.

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

A 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa

[2010 O/N-12 (7)]

34.

Three substances, R, S and T, have physical properties as shown.

substance	R	S	T
mp/°C	801	2852	3550
bp/°C	1413	3600	4827
electrical conductivity of solid	poor	poor	good

What could be the identities of R, S and T?

	R	S	T
A	MgO	NaCl	C [graphite]
B	MgO	NaCl	SiO_2
C	NaCl	MgO	C [graphite]
D	NaCl	MgO	SiO_2

[2011 M/J-11 (10)]

35.

Which are features of the structure of metallic copper?

1 a lattice of ions

2 delocalised electrons

3 ionic bonds

[2011 M/J-11 (32)]

36.

When a sample of a gas is compressed at constant temperature from 1500 kPa to 6000 kPa, its volume changes from 76.0 cm^3 to 20.5 cm^3.

Which statements are possible explanations for this behaviour?

1 The gas behaves non-ideally.

2 The gas partially liquefies.

3 Gas is adsorbed on to the vessel walls.

[2011 M/J-12 (32)]

37.

Which equations apply to an ideal gas?
[p = pressure, V = volume, M = molar mass, ρ = density, c = concentration, R = gas constant, T = temperature]

1 $p = \frac{\rho RT}{M}$ **2** $pV = MRT$ **3** $pV = \frac{cRT}{M}$

[2011 M/J-12 (33)]

38.

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

[2011 O/N-11 (5)]

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39.

Three compounds have the physical properties shown in the table.

compound	P	Q	R
melting point / °C	2852	993	−119
boiling point / °C	3600	1695	39
conductivity (solid)	poor	poor	poor
conductivity (liquid)	good	good	poor
conductivity (aqueous)	insoluble	good	insoluble

What might be the identities of **P**, **Q** and **R**?

	P	Q	R
A	MgO	KC*l*	NH_3
B	MgO	NaF	C_2H_5Br
C	SiO_2	KC*l*	C_2H_5Br
D	SiO_2	NaF	HC*l*

[2011 O/N-12 (6)]

40.

The use of sucrose in food processing depends in part on osmotic pressure, symbol Π.

In dilute solution, Π varies with concentration in a similar way to gas behaviour. The equation $\Pi V = nRT$ can be used, where n is the number of moles of solute molecules contained in volume V at temperature T. The number of moles of solvent molecules should be ignored.

Under aqueous acidic conditions sucrose is hydrolysed.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{fructose}}{CH_2OH(CHOH)_3COCH_2OH}$$

What can be deduced from this hydrolysis equation?

	the osmotic pressure	glucose and fructose are
A	decreases	optical isomers
B	decreases	structural isomers
C	increases	optical isomers
D	increases	structural isomers

[2011 O/N-12 (9)]

41.

Which are assumptions of the kinetic theory of gases and hence of the ideal gas equation, $PV = nRT$?

1 Molecules move without interacting with one another except for collisions.

2 Intermolecular forces are negligible.

3 Intermolecular distances are much greater than the molecular size.

[2011 O/N-12 (33)]

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42.

Use of the Data Booklet is relevant to this question.

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

[2012 M/J-11 (6)]

43.

Under which set of conditions is a gas most likely to behave ideally?

	temperature	pressure
A	high	high
B	high	low
C	low	high
D	low	low

[2012 M/J-11 (8)]

44.

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

$$pV = nRT$$

where each symbol has its usual meaning.

Which statements are correct?

1 One mole of an ideal gas occupies the same volume under the same conditions of temperature and pressure.

2 The density of an ideal gas at constant pressure is inversely proportional to the temperature, *T*.

3 The volume of a given mass of an ideal gas is doubled if its temperature is raised from 25 °C to 50 °C at constant pressure.

[2012 M/J-11 (31)]

45.

Use of the Data Booklet is relevant to this question.

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

$$pV = nRT$$

0.96 g of oxygen gas is contained in a glass vessel of volume 7000 cm^3 at a temperature of 30 °C.

What is the pressure in the vessel?

A 1.1 kPa **B** 2.1 kPa **C** 10.8 kPa **D** 21.6 kPa

[2012 M/J-12 (6)]

46.

Use of the Data Booklet is relevant to this question.

The volume of a sample of ammonia is measured at a temperature of 60 °C and a pressure of 103 kPa. The volume measured is 5.37×10^{-3} m^3.

What is the mass of the sample of ammonia, given to two significant figures?

A 0.00019 g **B** 0.0034 g **C** 0.19 g **D** 3.4 g

[2012 O/N-11 (6)]

47.

Some car paints contain small flakes of silica, SiO_2.

In the structure of solid SiO_2

- each silicon atom is bonded to **x** oxygen atoms,
- each oxygen atom is bonded to **y** silicon atoms,
- each bond is a **z** type bond.

What is the correct combination of **x**, **y** and **z** in this statement?

	x	y	z
A	2	1	covalent
B	2	1	ionic
C	4	2	covalent
D	4	2	ionic

[2012 O/N-11 (8)]

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48.

Which of these substances have a giant structure?

1 silicon(IV) oxide

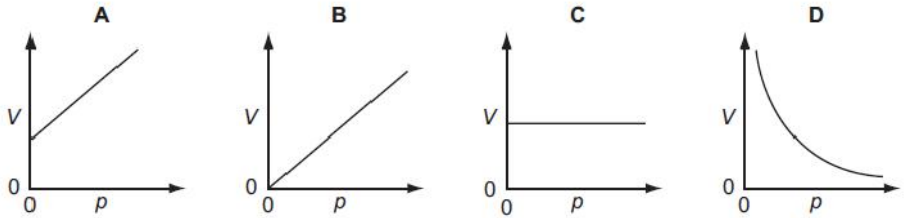
2 baked clay found in crockery

3 phosphorus(V) oxide

[2012 O/N-11 (33)]

49.

Which diagram shows the correct graph of V against p for a fixed mass of an ideal gas at constant temperature?



[2012 O/N-13 (1)]

50.

Use of the Data Booklet is relevant to this question.

The volume of a sample of ammonia was measured at a temperature of 40 °C and a pressure of 95 kPa. The volume measured was 4.32×10^{-5} m^3.

What is the mass of the sample of ammonia?

A 2.7×10^{-5} g **B** 2.1×10^{-4} g **C** 2.7×10^{-2} g **D** 2.1×10^{-1} g

[2012 O/N-13 (3)]

51.

Which would behave the **least** like an ideal gas at room temperature?

A carbon dioxide

B helium

C hydrogen

D nitrogen

[2013 M/J-11 (9)]

52.

The general gas equation can be used to calculate the M_r value of a gas.

For a sample of a gas of mass mg, which expression will give the value of M_r?

A $M_r = \frac{mpV}{RT}$ **B** $M_r = \frac{pVRT}{m}$ **C** $M_r = \frac{mRT}{pV}$ **D** $M_r = \frac{pV}{mRT}$

[2013 M/J-11 (10)]

53.

Ethanol has a boiling point of 78 °C. At 101 kPa and 79 °C ethanol vapour does not perfectly obey the gas equation $pV = nRT$.

What is the reason for this?

A Ethanol vapour is in equilibrium with ethanol liquid at 79 °C.

B There are intermolecular forces between the molecules of ethanol vapour.

C The vapourisation of ethanol liquid is an endothermic process.

D Vapours will not obey the gas equation perfectly at such a low pressure.

[2013 M/J-12 (7)]

54.

Which **least** resembles an ideal gas at room temperature and pressure?

A ammonia

B helium

C hydrogen

D methane

[2013 M/J-13 (6)]

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55.

Use of the Data Booklet is relevant to this question.

When 0.15 g of an organic compound is vaporised, it occupies a volume of 65.0 cm^3 at 405 K and 1.00×10^5 Nm^{-2}.

Using the expression $pV = nRT$, which of the following expressions should be used to calculate the relative molecular mass, M_r, of the compound?

A $\dfrac{0.15 \times 65 \times 10^{-6} \times 1 \times 10^5}{8.31 \times 405}$

B $\dfrac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-3}}$

C $\dfrac{0.15 \times 65 \times 10^{-3} \times 1 \times 10^5}{8.31 \times 405}$

D $\dfrac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-6}}$

[2013 M/J-13 (7)]

56.

Which compound is the only gas at room temperature and pressure?

A $CH_3CH_2CH_2NH_2$ $M_r = 59.0$

B $CH_3CH_2CH_2OH$ $M_r = 60.0$

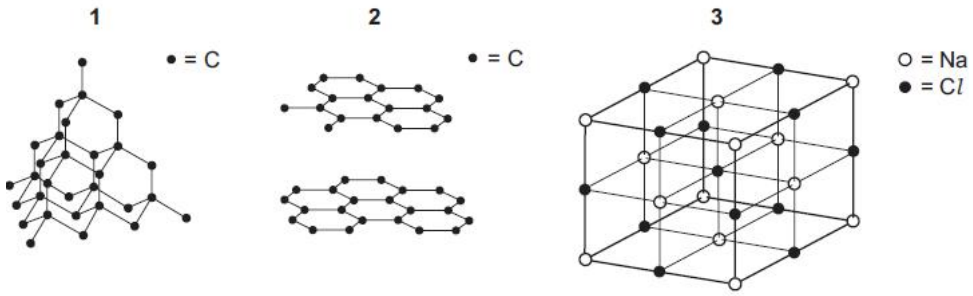
C CH_2OHCH_2OH $M_r = 62.0$

D CH_3CH_2Cl $M_r = 64.5$

[2013 M/J-13 (8)]

57.

Which diagrams represent part of a giant molecular structure?



[2013 M/J-13 (34)]

58.

Use of the Data Booklet is relevant to this question.

The approximate percentage composition of the atmosphere on four different planets is given in the table below.

The density of a gas may be defined as the mass of 1 dm^3 of the gas measured at s.t.p.

Which mixture of gases has the greatest density?

	planet	major gases/ % by number of molecules
A	Jupiter	H_2 89.8, He 10.2
B	Neptune	H_2 80.0, He 19.0, CH_4 1.0
C	Saturn	H_2 96.3, He 3.25, CH_4 0.45
D	Uranus	H_2 82.5, He 15.2, CH_4 2.3

[2013 O/N-11 (8)]

59.

Measured values of the pressure, volume and temperature of a known mass of a gaseous compound are to be substituted into the equation $pV = nRT$.

The measurements are used to calculate the relative molecular mass, M_r, of a compound.

Which conditions of pressure and temperature would give the most accurate value of M_r?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

[2013 O/N-13 (7)]

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60.

Use of the Data Booklet is relevant to this question.

When an evacuated fluorescent light tube of volume 300 cm^3 is filled with a gas at 300 K and 101 kPa, the mass of the tube increases by 1.02 g. The gas obeys the ideal gas equation $pV = nRT$.

What is the identity of the gas?

A argon

B krypton

C neon

D nitrogen

[2013 O/N-13 (9)]

61.

Use of the Data Booklet is relevant to this question.

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 1.00×10^5 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

[2014 M/J-11 (2)]

62.

The table shows the physical properties of four substances.

Which substance has a giant covalent structure?

	melting point / °C	boiling point / °C	electrical conductivity of solid	electrical conductivity of liquid	electrical conductivity of aqueous solution
A	–119	39	poor	poor	insoluble
B	–115	–85	poor	poor	good
C	993	1695	poor	good	good
D	1610	2230	poor	poor	insoluble

[2014 M/J-11 (4)]

63.

Substances X, Y and Z are all solids. Some of their physical properties are given in the table.

substance	X	Y	Z
melting point / °C	772	114	1610
boiling point / °C	1407	183	2205
electrical conductivity of the liquid state	conducts	does not conduct	does not conduct

What type of lattice could each substance have?

	X	Y	Z
A	giant molecular	simple molecular	ionic
B	ionic	giant molecular	simple molecular
C	ionic	simple molecular	giant molecular
D	simple molecular	ionic	giant molecular

[2014 M/J-12 (2)]

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64.

Use of the Data Booklet is relevant to this question.

In an experiment, 12.0 dm^3 of oxygen, measured under room conditions, is used to burn completely 0.10 mol of propan-1-ol.

What is the final volume of gas, measured under room conditions?

A 7.20 dm^3 **B** 8.40 dm^3 **C** 16.8 dm^3 **D** 18.00 dm^3

[2014 M/J-12 (9)]

65.

A 10.0 cm^3 bubble of an ideal gas is formed on the sea bed where it is at a pressure of 2020 kPa.

Just below the sea surface the pressure is 101 kPa and the temperature is the same as the sea bed.

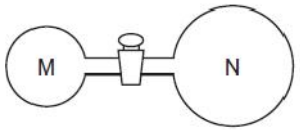
What is the volume of the bubble when it rises to just below the sea surface?

A 10.0 cm^3 **B** 20.2 cm^3 **C** 200 cm^3 **D** 2 020 000 cm^3

[2014 M/J-13 (7)]

66.

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



M contains helium at 20 °C at a pressure of 1×10^5 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 3.18×10^4 Pa

B 4.24×10^4 Pa

C 1.25×10^5 Pa

D 5.09×10^5 Pa

[2014 O/N-11 (4)]

67.

A student borrowed a friend's chemistry notes and copied out the notes in the box below.

Which statements are correct?

A gas behaves **less** like an ideal gas when the gas
1 is at low pressure.
2 is at low temperature.
3 can be easily liquefied.

[2014 O/N-11 (34)]

68.

Which row shows properties of a ceramic material?

	melting point /K	boiling point /K	conductivity of solid
A	156	352	none
B	922	1380	good
C	2130	2943	good
D	3125	3873	none

[2014 O/N-13 (3)]

69.

Use of the Data Booklet is relevant to this question.

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

[2014 O/N-13 (9)]

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States of matter – 2021 AS

1. Nov/2021/Paper_12/No.7

The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

Some information for a range of hydrides is given.

hydride	boiling point / K
PH_3	185
HCl	188
HF	293
H_2O	373

Which statement and reason about these hydrides is correct?

A The boiling point of PH_3 is much lower than the boiling point of H_2O because PH_3 does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.

B The boiling point of HF is higher than the boiling point of HCl because the bond energy of H–F is greater than the bond energy of H–Cl.

C The boiling point of H_2O is higher than the boiling point of HF because each hydrogen bond between the H_2O molecules is stronger than each hydrogen bond between HF molecules.

D The boiling points of PH_3 and HCl are similar because the molecules of PH_3 and HCl have the same number of electrons and similar intermolecular forces.

2. Nov/2021/Paper_12/No.8

The general gas equation can be used to calculate the value of the M_r of a gas.

For a sample of a gas of mass m grams, which expression will give the value of M_r?

A $M_r = \frac{mRT}{pV}$ **B** $M_r = \frac{pVRT}{m}$ **C** $M_r = \frac{mpV}{RT}$ **D** $M_r = \frac{pV}{mRT}$

3. Nov/2021/Paper_13/No.5

Which type of interaction exists between water molecules and metal cations in aqueous solution?

A dipole-dipole interactions

B hydrogen bonds

C ion-dipole interactions

D ionic bonds

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4. Nov/2021/Paper_13/No.6

Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?

A $CO_2(g)$ **B** $H_2(g)$ **C** Ne(g) **D** $NH_3(g)$

5. Nov/2021/Paper_13/No.33

Ethylene glycol, $HOCH_2CH_2OH$, is used as a de-icer. It allows ice to melt at temperatures below 0 °C.

Which statements are correct?

1 Ethylene glycol disrupts the extensive network of hydrogen bonds in ice.

2 Ethylene glycol molecules form hydrogen bonds with other ethylene glycol molecules.

3 Ethylene glycol molecules will dissolve in the water formed from the ice.

6. March/2021/Paper_12/No/.5

In which substance are the only intermolecular forces temporary dipole-induced dipole attractions?

A hydrogen chloride

B methanol

C octane

D water

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7. June/2021/Paper_11/No.8

Which gas would behave most like an ideal gas under room conditions?

A helium

B nitrogen

C ammonia

D krypton

8. June/2021/Paper_12/No.5

Flask Q contains 5 dm^3 of helium at 12 kPa pressure. Flask R contains 10 dm^3 of neon at 6 kPa pressure.

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

A 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa

9. June/2021/Paper_12/No.6

Sodium chloride, water and air represent three states of matter – solid, liquid and gas.

Which row is correct?

	sodium chloride	water	air
A	particles held in rigid structure	can easily be compressed	can easily be compressed
B	particles stationary	particles move	cannot easily be compressed
C	particles stationary	particles stationary	particles move
D	resistant to change of shape	cannot easily be compressed	can easily be compressed

10. June/2021/Paper_13/No.24

A mixture of ethanol and methanol is burned in oxygen to produce 35 cm^3 of CO_2 and 55 cm^3 of H_2O.

Complete combustion occurs and the volumes of both products are measured at 101 kPa and 120 °C.

What is the molar ratio, ethanol : methanol, in the mixture?

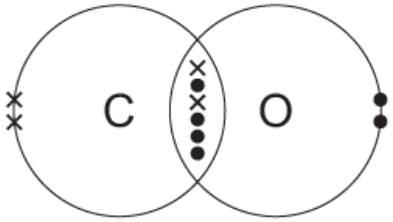
A 1 : 3 **B** 2 : 3 **C** 3 : 2 **D** 3 : 1

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11. June/2021/Paper_21/No.2

Carbon monoxide gas, CO(g), and nitrogen gas, $N_2(g)$, are both diatomic molecules.

(a) The diagram shows the arrangement of outer electrons in a molecule of CO(g).



(i) State **one** similarity and **one** difference in the way the atoms in a carbon monoxide molecule are bonded together compared to the atoms in a nitrogen molecule.

.....

.....

..... [2]

(ii) The table states the electronegativity values of carbon, nitrogen and oxygen atoms.

	C	N	O
electronegativity	2.5	3.0	3.5

Use the electronegativity values and relevant details from the *Data Booklet* to complete the table below.

	N_2	CO
number of electrons per molecule		
type(s) of intermolecular (van der Waals') force		

[2]

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(b) $N_2(g)$ is less reactive than CO(g) even though $N_2(g)$ has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than $N_2(g)$.

.....

..... [1]

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

..... [1]

(ii) Explain why $N_2(g)$ behaves more like an ideal gas than CO(g) does at 20.0 °C and 101 kPa.

.....

.....

..... [2]

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(d) Calculate the amount, in mol, of pure nitrogen gas which occupies 100 cm^3 at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol
[3]

[Total: 11]

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12. June/2021/Paper_22/No.2

The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S, is a crystalline solid with a melting point of 938 °C. It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

..... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....

..... [2]

(b) Carbon monoxide, CO, is a gas at room temperature and pressure. It contains a coordinate bond.

(i) Explain what is meant by *coordinate bond*.

.....

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in CO.

Show the electrons belonging to the C atom as ×.

Show the electrons belonging to the O atom as ●.

[2]

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(c) Nitrogen, N_2, is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

.....

.....

.....

..... [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of $N_2(g)$ and CO(g).

	$N_2(g)$	CO(g)
number of electrons per molecule	14	14
presence of a dipole moment	✗	✓
boiling point/°C	–195.8	–191.5
intermolecular forces (van der Waals')		

[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

..... [1]

[Total: 13]

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States of matter – 2022 June AS Chemistry 9701

1. June/2022/Paper_11/No.8

For which pair is the boiling point of the first compound **higher** than the boiling point of the second compound?

A CH_3CH_2OH and CH_3CH_2SH

B $CH_3CO_2CH_3$ and $CH_3CH_2CO_2H$

C CH_3OCH_3 and CH_3CH_2OH

D CH_3CH_2CHO and $CH_3CH_2CO_2H$

2. June/2022/Paper_12/No.7

Which gas will behave **least** like an ideal gas at 150 °C and 101 kPa?

A ammonia

B fluorine

C krypton

D steam

3. June/2022/Paper_12/No.8

When an evacuated glass bulb of volume 200 cm^3 is filled with a gas at 300 K and 101 kPa, the mass of the bulb increases by 0.68 g. The gas obeys the ideal gas equation.

What is the identity of the gas?

A argon

B krypton

C neon

D nitrogen

4. June/2022/Paper_13/No.7

This question is about buckminsterfullerene, graphite, iodine and diamond.

How many of these substances have a simple molecular structure?

A 0 **B** 1 **C** 2 **D** 3

States of matter – 2022 Nov AS Chemistry 9701

1. Nov/2022/Paper_12/No.14

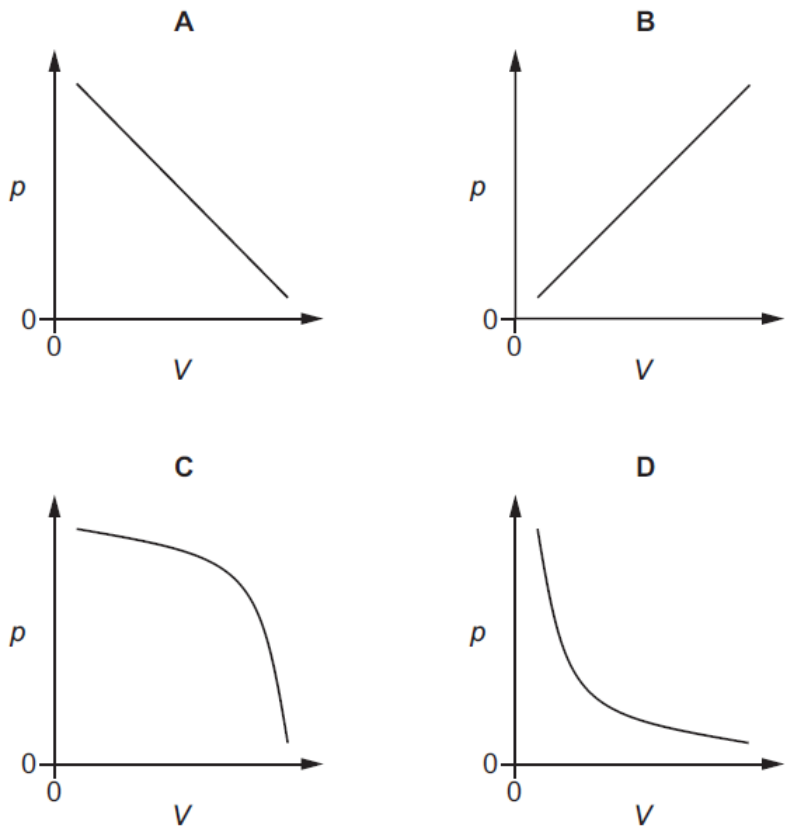
Each of the substances shown is gaseous.

Which substance is most likely to show ideal behaviour in the conditions shown?

	substance	temperature / K	pressure / Pa
A	carbon dioxide	250	1.00×10^5
B	hydrogen chloride	1000	1.00×10^6
C	nitrogen	1000	1.00×10^5
D	oxygen	250	1.00×10^6

2. Nov/2022/Paper_12/No.15

Which graph represents the variation of pressure *p* and volume *V* of a sample of an ideal gas at constant temperature?



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3. Nov/2022/Paper_22/No.2(d)

(d) A 3.30 g sample of a Period 3 chloride is heated to 500 K in a sealed flask.
At this temperature, the chloride is a gas of volume 250 cm^3 and the pressure in the flask is 323 kPa.

Use the ideal gas equation $pV = nRT$ to calculate the M_r of the Period 3 chloride.
Deduce its formula.

M_r = ...

formula of Period 3 chloride = ...
[3]

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States of matter – 2023 AS Chemistry 9701

1. Nov/2023/Paper_ 9701/11/No.7

When an evacuated tube of volume 400 cm^3 is filled with gas at 300 K and 101 kPa, the mass of the tube increases by 0.65 g.

Assume the gas behaves as an ideal gas.

What is the identity of the gas?

A argon

B helium

C krypton

D neon

2. Nov/2023/Paper_ 9701/11/No.8

Nitrogen, N_2, and carbon monoxide, CO, both have M_r = 28.

The boiling point of N_2 is 77 K.

The boiling point of CO is 82 K.

What could be responsible for this difference in boiling points?

A CO molecules have a permanent dipole; the N_2 molecules are **not** polar.

B N_2 has σ and π bonding; CO has σ bonding only.

C N_2 has a strong N≡N bond; CO has a C=O bond.

D The CO molecule has more electrons than the N_2 molecule.

3. Nov/2023/Paper_ 9701/12/No.9

At a temperature of 2500 K and a pressure of 1.00×10^{-4} Pa, a sample of 0.321 g of sulfur vapour has a volume of 2.08×10^{6} m^3.

What is the molecular formula of sulfur under these conditions?

A S **B** S_2 **C** S_4 **D** S_8

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4. Nov/2023/Paper_ 9701/12/No.10

In the structure of solid SiO_2

each silicon atom is bonded to x oxygen atoms

each oxygen atom is bonded to y silicon atoms

each bond is a z type bond.

What is the correct combination of x, y and z in these statements?

	x	y	z
A	2	1	covalent
B	2	1	ionic
C	4	2	covalent
D	4	2	ionic

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5. Nov/2023/Paper_ 9701/21/No.3(d)

(d) Molten $KClO_3$ reacts with glucose, $C_6H_{12}O_6$.

$$4KClO_3 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 4KCl$$

$KClO_3$ melts at 630 K. At this temperature, both CO_2 and H_2O are gases.

(i) Use the ideal gas equation to calculate the volume, in m^3, of one mole of gas at 630 K and 1.00×10^5 Pa.

Show your working. Give your answer to 3 significant figures.

volume of 1 mol of gas = ... m^3
[1]

(ii) 5.00 g of $C_6H_{12}O_6$ reacts completely with molten $KClO_3$.

Use your answer to **(d)(i)** to calculate the total volume of gas released at 630 K and 1.00×10^5 Pa in this reaction.

(If you were unable to answer **(d)(i)**, use 0.0463 m^3 in this question. This is **not** the correct answer to **(d)(i)**.)

total volume of gas released = ... m^3
[2]

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6. June/2023/Paper_9701/11/No.6

In the sodium chloride lattice the number of chloride ions that surround each sodium ion is called the coordination number of the sodium ions.

What are the coordination numbers of the sodium ions and the chloride ions in the sodium chloride lattice?

	coordination number of sodium ions	coordination number of chloride ions
A	4	6
B	6	4
C	6	6
D	8	6

7. June/2023/Paper_9701/11/No.13

In this question you should assume that the gas formed behaves as an ideal gas.

A 1.7 g sample of Mg reacts with 50.0 cm^3 of 2.2 mol dm^{-3} HC*l* at 303 K and 110 400 Pa.

Which volume of gas is produced, measured under these conditions?

A 1.3 dm^3 **B** 1.6 dm^3 **C** 2.5 dm^3 **D** 5.0 dm^3

8. June/2023/Paper_9701/11/No.16

For which compound is there the greatest percentage loss of mass on strong heating?

A anhydrous calcium carbonate

B anhydrous calcium nitrate

C anhydrous magnesium carbonate

D anhydrous magnesium nitrate

9. June/2023/Paper_9701/12/No.8

The volume of a vessel is 1.20×10^{-3} m^3. It contains pure argon at a pressure of 1.00×10^5 Pa, and at a temperature of 25.0 °C. Under these conditions it can be assumed that argon behaves as an ideal gas.

Which mass of argon does it contain?

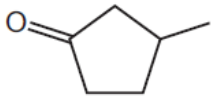
A 0.0485 g **B** 1.93 g **C** 10.4 g **D** 23.0 g

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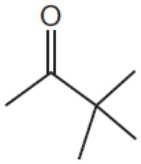
10. June/2023/Paper_9701/12/No.25

Which compound has the molecular formula $C_6H_{10}O$?

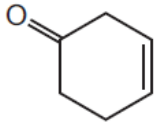
A



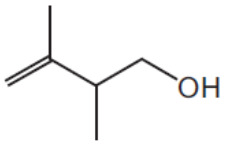
B



C



D



11. June/2023/Paper_9701/13/No.7

Which assumptions are made about ideal gases?

1 Ideal gases contain molecules with no mass.

2 Ideal gases contain molecules with no volume.

3 Ideal gases have no intermolecular forces.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

12. June/2023/Paper_9701/13/No.8

A 200 cm^3 sample of water has an amount of oxygen gas dissolved in it.

This amount of oxygen gas has a volume of 6.00 cm^3 when measured at 1.00×10^5 Pa and 35 °C.

What is the concentration of oxygen gas in the water? (You should assume that oxygen behaves as an ideal gas.)

A 2.34×10^{-4} mol dm^{-3}

B 1.17×10^{-3} mol dm^{-3}

C 1.25×10^{-3} mol dm^{-3}

D 1.03×10^{-2} mol dm^{-2}

13. June/2023/Paper_9701/13/No.9

Which statement explains why buckminsterfullerene has a lower melting point than graphite?

A Buckminsterfullerene exists as discrete molecules with weak intermolecular bonding.

B Graphite is partly ionic as its structure contains mobile electrons and it conducts electricity.

C The carbon–carbon bonds in buckminsterfullerene are shorter and more strained.

D The mobile electrons in graphite mean it has a metallic structure.

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14. March/2023/Paper_9701/12/No.9

Under which conditions will nitrogen behave most like an ideal gas?

	temperature	pressure
A	low	high
B	high	low
C	low	low
D	high	high

15. March/2023/Paper_9701/12/No.11

Molten aluminium chloride has a simple molecular structure. Each molecule consists of two aluminium atoms and six chlorine atoms.

Which statement is correct?

A All the chlorine atoms in 1 g of molten aluminium chloride have the same mass.

B One mole of molten aluminium chloride contains 6.02×10^{23} aluminium atoms.

C One mole of molten aluminium chloride contains 3.61×10^{24} chlorine atoms.

D The empirical formula of molten aluminium chloride is Al_2Cl_6.

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