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LECTURE

Atomic Structure & Chemical Bonding

Multiple Choice Questions (9701)

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Fahad H. Ahmad

Atomic Structure : Protons, Neutrons, Electrons

- 2 Neutrons are passed through an electric field. The mass of one neutron relative to $\frac{1}{12}$ the mass of a ^{12}C atom and any deflection in the electric field is recorded.

Which row is correct?

	mass of neutron	behaviour of beam of neutrons in an electric field
A	0	deflected
B	1	deflected
C	0	not deflected
D	1	not deflected

s/18/qp13

- 1 In which pair do the atoms contain the same number of neutrons?

- A $^{11}_5\text{B}$ and $^{12}_6\text{C}$ → same neutrons
 B ^7_3Li and ^9_4Be
 C $^{24}_{12}\text{Mg}$ and $^{28}_{14}\text{Si}$
 D $^{14}_7\text{N}$ and $^{16}_8\text{O}$

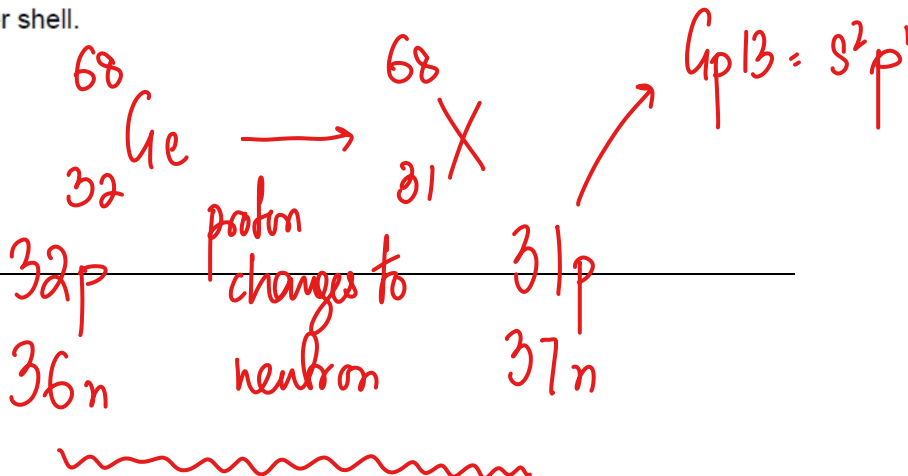
w/17/qp12

- 5 The ^{68}Ge isotope is medically useful because it undergoes a natural radioactive process to give an isotope of a different element, ^{68}X , which can be used to detect tumours. This transformation of ^{68}Ge occurs when an electron enters the nucleus and changes a proton into a neutron.

Which statement about the composition of an atom of ^{68}X is correct?

- A It has 4 electrons in its outer p orbitals. ✗
 B It has 13 electrons in its outer shell. ✗
 C It has 37 neutrons.
 D Its proton number is 32.

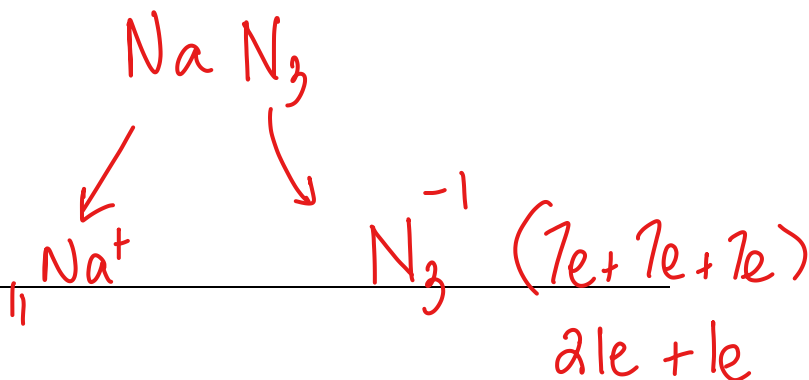
w/16/qp11



- 4 Sodium azide, NaN_3 is an explosive used to inflate airbags in cars when they crash. It consists of positive sodium ions and negative azide ions.

What are the numbers of electrons in the sodium ion and the azide ion?

	sodium ion	azide ion
A	10	20
B	10	22
C	12	20
D	12	22

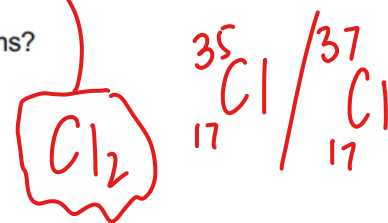


w/16/qp11

- 31 The relative molecular mass, M_r , of a particular sample of chlorine is 72.0.

Which properties of the atoms in this sample will be the same for all of the atoms?

- 1 radius
2 nucleon number X
3 isotopic mass X

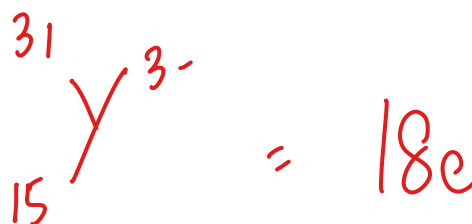


w/15/qp12

- 1 The ion Y^{3-} contains 18 electrons and has a mass number of 31.

How many protons and neutrons does Y^{3-} contain?

	protons	neutrons
A	15	16
B	15	18
C	18	13
D	21	10



s/17/qp13

- 1 In which species are the numbers of protons, neutrons and electrons all different?

- A $^{19}_9\text{F}^-$ B $^{23}_{11}\text{Na}^+$ C $^{31}_{15}\text{P}$ D $^{32}_{16}\text{S}^{2-}$
- 10e, 11p, 12n 15p/15e 16p/16n

s/17/qp12

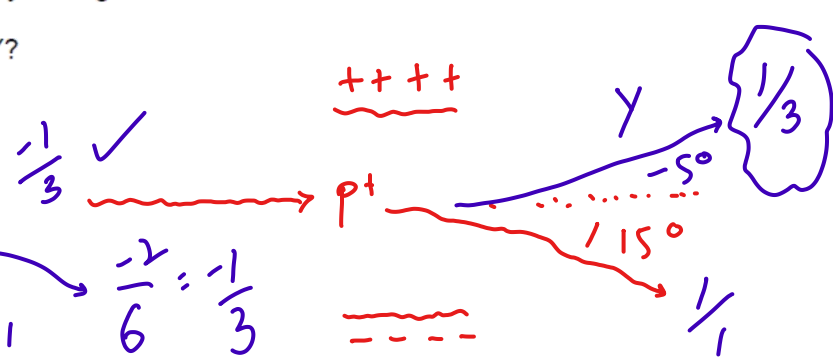
31 Beams of charged particles are deflected by an electric field. In identical conditions the angle of deflection of a particle is proportional to its charge/mass ratio.

In an experiment, protons are deflected by an angle of $+15^\circ$. In another experiment under identical conditions, particle Y is deflected by an angle of -5° .

What could be the composition of particle Y?

	protons	neutrons	electrons
1 ✓	1	2	2
2 ✓	3	3	5
3 ✗	4	5	1

deflection ∝ charge/m
 $P = \frac{1}{3}$
 $Y = \frac{1}{3}$



s/17/qp11

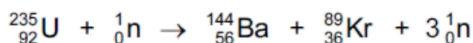
31 X is a particle with 18 electrons and 20 neutrons.

What could be the symbol of X?

- 1 ${}^{38}_{18}\text{Ar}$
- 2 ${}^{40}_{20}\text{Ca}^{2+}$
- 3 ${}^{39}_{19}\text{K}^+$

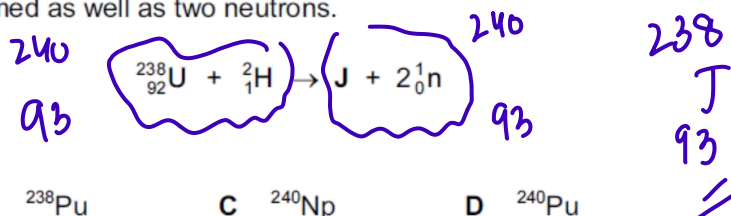
s/16/qp11

4 When nuclear reactions take place, the elements produced are different from the elements that reacted. Nuclear equations, such as the one below, are used to represent the changes that occur.



The nucleon (mass) number total is constant at 236 and the proton number total is constant at 92.

In another nuclear reaction, uranium-238 is reacted with deuterium atoms, ${}^2_1\text{H}$. An isotope of a new element, J, is formed as well as two neutrons.



What is isotope J?

- A ${}^{238}_{93}\text{Np}$
- B ${}^{238}_{93}\text{Pu}$
- C ${}^{240}_{93}\text{Np}$
- D ${}^{240}_{93}\text{Pu}$

s/16/qp11

- 31 The technetium-99 isotope, ^{99}Tc , is radioactive and has been found in lobsters and seaweed near to nuclear fuel reprocessing plants.

Which statements about an atom of ^{99}Tc are correct?

- 1 It has 13 fewer protons than neutrons.
- 2 It forms $^{99}\text{Tc}^{2+}$ which has 45 electrons.
- 3 It has 56 nucleons.

s/15/qp13

- 31 Use of the Data Booklet is relevant to this question.

Which statements about the phosphide ion, $^{31}\text{P}^{3-}$, and the chloride ion, $^{35}\text{Cl}^-$, are correct?

- 1 They have the same number of electrons. ✓
- 2 They have the same number of neutrons. ✗
- 3 They have the same number of protons. ✗

s/15/qp12

- 31 Use of the Data Booklet is relevant to this question.

The isotope ^{99}Tc is radioactive and has been found in lobsters and seaweed adjacent to nuclear fuel reprocessing plants.

Which statements are correct about an atom of ^{99}Tc ?

- 1 It has 13 more neutrons than protons.
- 2 It has 43 protons.
- 3 It has 99 nucleons.

s/15/qp11

- 3 Drinking water may contain dissolved calcium hydrogencarbonate, $\text{Ca}(\text{HCO}_3)_2$.

How many electrons are present in a hydrogencarbonate anion?

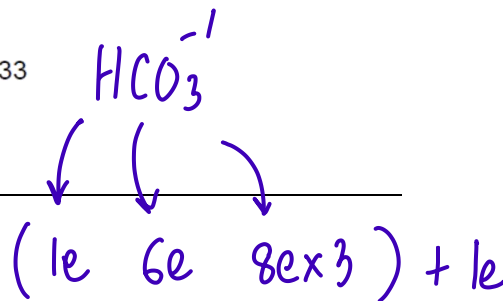
A 30

B 31

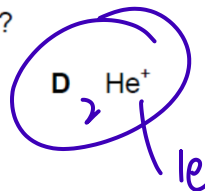
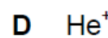
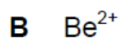
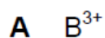
C 32

D 33

m/18/qp12

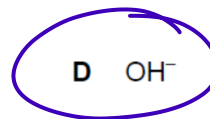
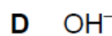
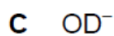
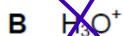
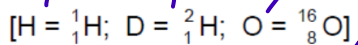


4 Which species contains the smallest number of electrons?



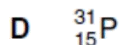
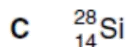
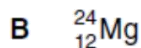
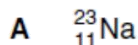
m/16/qp12

3 Which ion has both more electrons than protons and more protons than neutrons?



m/16/qp12

3 Which isotope of an element in the third period of the Periodic Table contains the same number of neutrons as ${}^{32}_{16}S$?



s/03/qp1

31 The isotope cobalt-60 (${}^{60}_{27}Co$) is used to destroy cancer cells in the human body.

Which statements about an atom of cobalt-60 are correct?

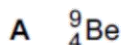
1 It contains 33 neutrons. ✓

2 Its nucleus has a relative charge of 27+. ✓

3 It has a different number of neutrons from the atoms of other isotopes of cobalt. ✓

s/04/qp1

4 In which species are the numbers of electrons and neutrons equal?



s/05/qp1

Handwritten notes for question 4: "10e, 10n" written below D.

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

Which element is likely to have an electronegativity similar to that of aluminium?

- A barium
- B beryllium
- C magnesium
- D strontium

← diagonal elements have similar electronegativity

s/05/qp1

4 A radioactive isotope of thallium, ${}_{81}^{201}\text{Tl}$, is used to assess damage in heart muscles after a heart attack.

Which statement about ${}_{81}^{201}\text{Tl}$ is correct?

- A This isotope has a nucleon number of 120. X
- B The number of electrons in one atom of this isotope is 81.
- C The number of neutrons in one atom of this isotope is 201.
- D ${}_{82}^{201}\text{X}$ is an isotope of ${}_{81}^{201}\text{Tl}$. X

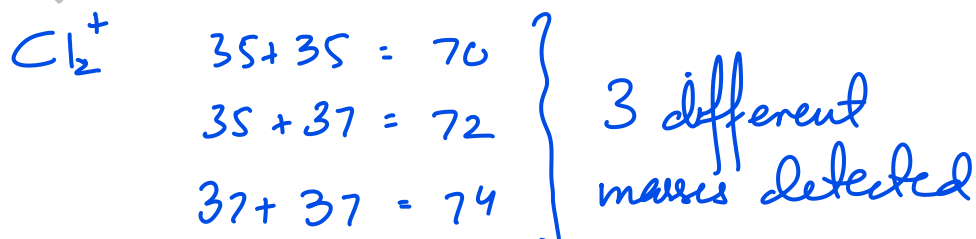
s/06/qp1

2 A sample of chlorine containing isotopes of mass numbers 35 and 37 was analysed in a mass-spectrometer.

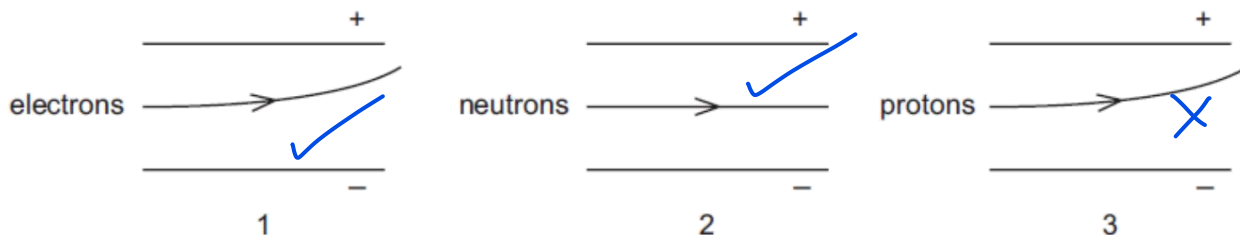
How many peaks corresponding to Cl_2^+ were recorded?

- A 2
- B 3
- C 4
- D 5

s/06/qp1



4 The diagrams show the possible paths of subatomic particles moving in an electric field in a vacuum.



Which diagrams are correct?

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

s/07/qp1

3 John Dalton's atomic theory, published in 1808, contained four predictions about atoms.

Which of his predictions is still considered to be correct?

- A Atoms are very small in size. ✓
- B No atom can be split into simpler parts. ✗
- C All the atoms of a particular element have the same mass. ✗
- D All the atoms of one element are different in mass from all the atoms of other elements. ✗

s/07/qp1

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

The technetium-99 isotope (^{99}Tc) is radioactive and has been found in lobsters and seaweed adjacent to nuclear fuel reprocessing plants.

Which statements are correct about an atom of ^{99}Tc ?

- 1 It has 13 more neutrons than protons. ✓
- 2 It has 43 protons. ✓
- 3 It has 99 nucleons. ✓



s/07/qp1



- 3 Skin cancer can be treated using a radioactive isotope of phosphorus, $^{32}_{15}\text{P}$. A compound containing the phosphide ion $^{32}_{15}\text{P}^{3-}$, wrapped in a plastic sheet, is strapped to the affected area.

What is the composition of the phosphide ion, $^{32}_{15}\text{P}^{3-}$?

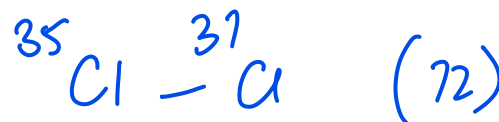
	protons	neutrons	electrons
A	15	17	18
B	15	17	32
C	17	15	17
D	32	17	15

s/08/qp1

- 31 On a scale in which the mass of a ^{12}C atom is 12 the relative molecular mass of a particular sample of chlorine is 72.

Which properties of the atoms in this sample are always the same?

- radius ✓
- nucleon number ✗
- isotopic mass ✗



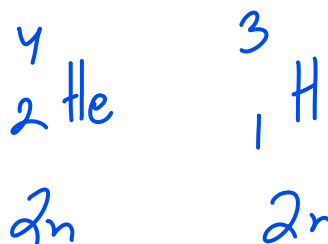
s/09/qp1

- 1 Helium, He, is the second element in the Periodic Table.

Tritium is the isotope of hydrogen ^3H .

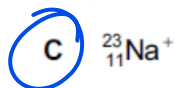
What is the same in an atom of ^4He and an atom of ^3H ?

- the number of electrons
- the number of neutrons**
- the number of protons
- the relative atomic mass



s/11/qp12

- 2 In which species are the numbers of protons, neutrons and electrons all different?



s/12/qp12



- 4 Unnilpentium is an artificial element. One of its isotopes is ${}_{105}^{262}\text{Unp}$.

Which of the following statements is correct?

A ${}_{105}^{262}\text{Unp}$ has a nucleon number of 105. ✗

B The atom ${}_{105}^{260}\text{X}$ is an isotope of ${}_{105}^{262}\text{Unp}$. ✓

C There are 262 neutrons in ${}_{105}^{262}\text{Unp}$.

D The proton number of ${}_{105}^{262}\text{Unp}$ is 262.

w/03/qp1

- 4 Use of the Data Booklet is relevant to this question.

It is now thought that where an element exists as several isotopes, the stable ones usually contain a 'magic number' of neutrons. One of these magic numbers is 126.

Which isotope is unstable?

A ${}^{209}\text{Bi}$

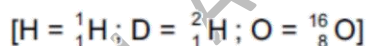
B ${}^{208}\text{Pb}$

C ${}^{210}\text{Po}$

D ${}^{208}\text{Tl}$

w/04/qp1

- 2 Which ion has more electrons than protons and more protons than neutrons?



A D^-

B H_3O^+

C OD^-

D OH^-

w/05/qp1

$$8p \ 1p = 9p$$

$$8e + 1e + 1e = 10e$$

$$8n + 0n = 8n$$

- 4 Use of the Data Booklet is relevant to this question.

Hard water contains calcium ions and hydrogencarbonate ions arising from dissolved calcium hydrogencarbonate, $\text{Ca}(\text{HCO}_3)_2$.

How many electrons are present in the hydrogencarbonate anion?

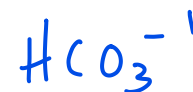
A 30

B 31

C 32

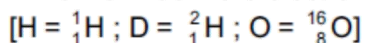
D 33

w/08/qp1



$$1e + 6e + 8 \times 3 + 1e$$

- 6 Which ion has more electrons than protons and more protons than neutrons?



A D^-

B H_3O^+

C OD^-

D OH^-

w/10/qp11

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

The ^{68}Ge isotope is medically useful because it undergoes a natural radioactive process to give a gallium isotope, ^{68}Ga , which can be used to detect tumours. This transformation of ^{68}Ge occurs when an electron enters the nucleus, changing a proton into a neutron.

Which statement about the composition of an atom of the ^{68}Ga isotope is correct?

A It has 4 electrons in its outer p subshell.

B It has 13 electrons in its outer shell.

C It has 37 neutrons. ✓

D Its proton number is 32. ✗

68
31 Ga

w/12/qp11

9 John Dalton's atomic theory, published in 1808, contained four predictions about atoms.

Which of his predictions is still considered to be correct?

A All atoms are very small in size.

B All the atoms of a particular element have the same mass.

C All the atoms of one element are different in mass from all the atoms of other elements.

D No atom can be split into simpler parts.

w/12/qp11

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

The isotope ^{99}Tc is radioactive and has been found in lobsters and seaweed adjacent to nuclear fuel reprocessing plants.

Which statements are correct about an atom of ^{99}Tc ?

1 It has 13 more neutrons than protons. ✓

2 It has 43 protons. ✓

3 It has 99 nucleons. ✓

w/12/qp11

32 The phosphide ion $^{31}_{15}\text{P}^{3-}$ and sulfide ion $^{32}_{16}\text{S}^{2-}$ have the same number of which sub-atomic particles?

1 neutrons ✓

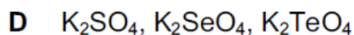
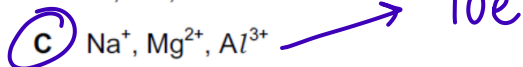
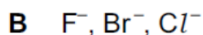
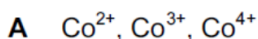
2 electrons ✓

3 protons ✗

w/12/qp13

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

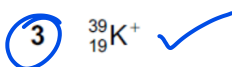
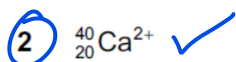
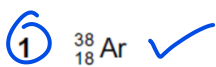
In which set do all species contain the same number of electrons?



w/13/qp11

31 X is a particle with 18 electrons and 20 neutrons.

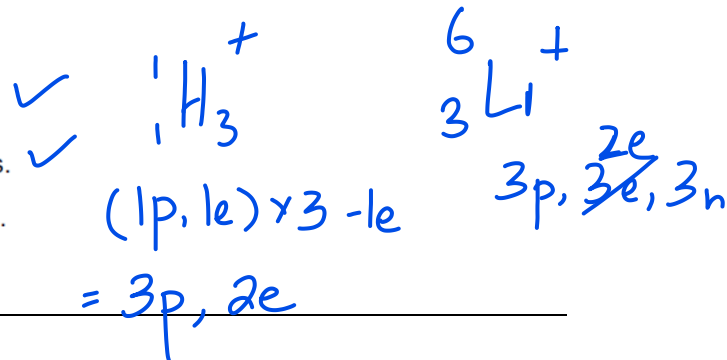
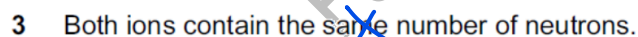
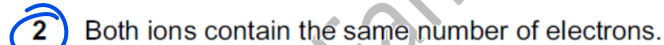
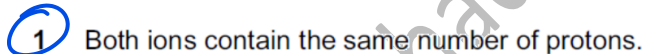
What could be the symbol of X?



w/13/qp11

31 The ${}^1\text{H}_3^+$ ion was first characterised by J. J. Thomson over a century ago. ${}^6\text{Li}$ is a rare isotope of lithium which forms the ${}^6\text{Li}^+$ ion.

Which statements are correct?



w/13/qp13

32 Which statements are correct when referring to the isotopes of a single element?

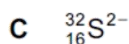
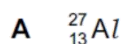
1 ✓ The isotopes have different masses.

2 ✓ The isotopes have different numbers of nucleons.

3 ✗ The isotopes have different chemical reactions. *same e⁻ configuration, same reactions*

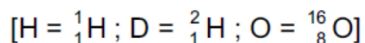
w/14/qp13

5 In which species are the numbers of protons, neutrons and electrons all different?



s/13/qp11

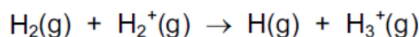
- 3 Which ion has more electrons than protons and more protons than neutrons?

A D^- B H_3O^+ C OD^-
 D OH^-
 $8e + 1e (+1e)$
 $8p + 1p$
 $8n + 0n$

s/13/qp12

- 4 Use of the Data Booklet is relevant to this question.

The most common ion-molecule reaction in gas clouds of the Universe is as shown.



What could be the composition of an H_3^+ ion?

	protons	neutrons	electrons
A	2	1	1
B	2	1	2
C	3	0	1
<input checked="" type="radio"/> D	3	0	2

 1_1H 1p, 1e, 0n

 H_3^+
 1p + 1p + 1p
 0n 0n 0n
 1e 1e 1e

s/14/qp13

- 31 In 2011 an international group of scientists agreed to add two new elements to the Periodic Table. Both elements had been made artificially and were called ununquadium (Uuq) and ununhexium (Uuh).

	Uuq	Uuh
proton number	114	116
nucleon number	289	292

Which statements about these elements are correct?

- One atom of Uuh has one more neutron than one atom of Uuq. ✓
- One Uuq^{2-} ion has the same number of electrons as one atom of Uuh. ✓
- One Uuh^+ ion has the same number of electrons as one Uuq^- ion. ✓

s/14/qp13

Size of Atom/Ion

12 The elements magnesium and sulfur each form doubly charged ions.

How do the atomic radii and ionic radii of these elements compare?

	atomic radius		ionic radius	atomic radius		ionic radius
A	Mg	>	Mg ²⁺	S	>	S ²⁻
B	Mg	>	Mg ²⁺	S	<	S ²⁻
C	Mg	<	Mg ²⁺	S	>	S ²⁻
D	Mg	<	Mg ²⁺	S	<	S ²⁻

S²⁻ has extra electrons which repel each other which makes S²⁻ bigger in size

Mg²⁺ has one less shell compared to Mg

s/17/qp12

35 Which statements describe a trend in Period 3 between every pair of adjacent elements from sodium to chlorine?

- 1 The atomic radius decreases. ✓
- 2 The 1st ionisation energy decreases.
- 3 The melting point decreases.

s/17/qp11

17 This question refers to isolated gaseous species.

The species F⁻, Ne and Na⁺ are isoelectronic. This means they have the same number of electrons. 9 10 11

In which order do their radii increase?

	smallest	→	largest
A	Na ⁺		Ne
B	F ⁻		Na ⁺
C	Na ⁺		F ⁻
D	Ne		Na ⁺

→ all have same e⁻ the one that has more protons is going to be attracting e⁻ strongly and will be smaller

s/15/qp13

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

In which option do all three particles have the same electronic configuration **and** the same number of neutrons?

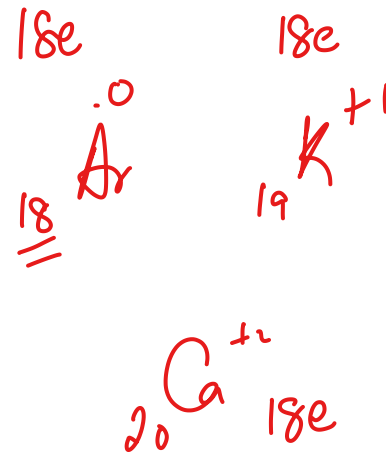
- A $^{15}\text{N}^{3-}$ $^{16}\text{O}^{2-}$ $^{19}\text{F}^{-}$
 7 8 9
 B $^{18}\text{O}^{2-}$ $^{19}\text{F}^{-}$ ^{20}Ne $\rightarrow 10n$
 8 9 10
 C $^{19}\text{F}^{-}$ ^{20}Ne $^{23}\text{Na}^{+}$
 9 10 11
 D ^{22}Ne ^{23}Na $^{24}\text{Mg}^{2+}$ X
 10 11 12

s/15/qp12

12 The following species contain the same number of electrons.

In which order do their radii increase?

	smallest radius	→	largest radius
A	Ar		Ca^{2+}
B	Ca^{2+}		K^{+}
C	Ca^{2+}		Ar
D	K^{+}		Ca^{2+}



s/05/qp1

all have same electrons,
 more protons, more
 attraction, smaller

12 Which group of particles is in order of increasing size?

- A N O F X
 B $^{7}\text{N}^{3-}$ $^{8}\text{O}^{2-}$ $^{9}\text{F}^{-}$ X
 C $^{11}\text{Na}^{+}$ $^{12}\text{Mg}^{2+}$ $^{13}\text{Al}^{3+}$ X
 D $^{11}\text{Na}^{+}$ Ne $^{9}\text{F}^{-}$ ✓

s/09/qp1

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

Sodium and sulfur react together to form sodium sulfide, Na₂S.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

	atomic radius	ionic radius
A	sodium > sulfur	sodium > sulfur
B	sodium > sulfur	sodium < sulfur
C	sodium < sulfur	sodium > sulfur
D	sodium < sulfur	sodium < sulfur

across period, atomic radius decreases, more protons, more attraction,

s/12/qp12

* +ve ion < -ve ion
shell lost smaller

14 The species Ar, K⁺ and Ca²⁺ are isoelectronic (have the same number of electrons).

In what order do their radii increase?

	smallest → largest		
A	Ar	Ca ²⁺	K ⁺
B	Ar	K ⁺	Ca ²⁺
C	Ca ²⁺	K ⁺	Ar
D	K ⁺	Ar	Ca ²⁺

Same e⁻
the one that has more protons is the smaller one

w/04/qp1

31 The relative molecular mass of a molecule of chlorine is 72.

Which properties of the atoms in this molecule are the same?

- radius ✓ → same shells, e⁻ configuration
- nucleon number ✗
- relative isotopic mass ✗

w/05/qp1

13 Which species has the largest radius?

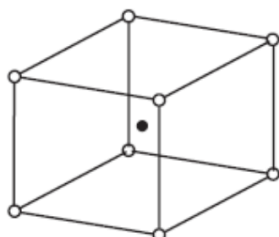
A P ³⁻	B Cl ⁻	C Ar	D K ⁺
15	17	18	19
18	18	18	15

w/07/qp1

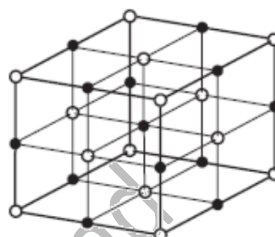
3 The table gives the radii, in pm, of some ions. [1 pm = 10^{-12} m]

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

*NaCl, MgO have same ratio
CsCl has different ratio*

w/10/qp12

19 Ar, Ca²⁺ and K⁺, contain the same number of electrons.

In which order do their radii increase?

	smallest radius	→	largest radius
A	Ar	K ⁺	Ca ²⁺
B	Ca ²⁺	Ar	K ⁺
C	Ca ²⁺	K ⁺	Ar
D	K ⁺	Ar	Ca ²⁺

w/11/qp12

- 16 The species Ne, Na⁺ and Mg²⁺ are isoelectronic. This means that they have the same number of electrons.

In which order do their radii increase?

	smallest	→	largest
A	Ne		Mg ²⁺
B	Ne		Na ⁺
C	Mg ²⁺		Na ⁺
D	Mg ²⁺		Ne

Handwritten notes: 1p under Mg²⁺ in row D, 11p under Na⁺ in row D, 10p under Ne in row D.



s/14/qp13

Fahad H. Ahmad

Atomic Structure: Electronic Configuration

3 The table refers to the electron distribution in the second shell of an atom with eight protons.

Which row is correct for this atom?

	orbital shape 		orbital shape 	
	orbital type	number of electrons	orbital type	number of electrons
A	p	2	s	4
B	<u>p</u>	<u>4</u>	<u>s</u>	<u>2</u>
C	s	2	p	4
D	s	4	p	2

8e
 $1s^2, 2s^2, 2p^4$

s/18/qp13

2 The electronic configuration of an atom of sulfur is $1s^2 2s^2 2p^6 3s^2 3p^4$.

How many valence shell and unpaired electrons are present in one sulfur atom?

	valence shell electrons	unpaired electrons
A	2	1
B	4	2
C	6	0
D	6	2

$3s^2, 3p^4$
 $3s^2$
 $3p_x^2, 3p_y^1, 3p_z^1$

s/18/qp12

1 This question refers to isolated gaseous atoms.

In which atom are all electrons paired?

A **Ba** B Br C S D Si

$6p^2, s^2$ $6p^1, s^2, p^5$ $6p^6, s^2, p^4$ $6p^4, s^2, p^2$

s/18/qp11

5 What is the electronic configuration of an isolated Ni²⁺ ion?

- A 1s²2s²2p⁶3s²3p⁶3d⁶4s²
- B 1s²2s²2p⁶3s²3p⁶3d⁸4s²
- C 1s²2s²2p⁶3s²3p⁶3d¹⁰4s²
- D** 1s²2s²2p⁶3s²3p⁶3d⁸

28 Ni²⁺
 1s², 2s², 2p⁶, 3s², 3p⁶, 3d⁸, ~~4s²~~

w/16/qp12

31 Which statements about orbitals in a krypton atom are correct?

- 1 The 1s and 2s orbitals have the same energy as each other but different sizes. ~~X~~
- 2** The third energy level (n=3) has three subshells and nine orbitals. ✓
- 3** The 3d subshell has five orbitals that have the same energy as each other in an isolated atom. ✓

36e
 1s
 2s 2p
 3s 3p 3d

w/15/qp13

31 Which statements about orbitals in a krypton atom are correct?

- 1 The 1s and 2s orbitals have the same energy as each other but different sizes.
- 2 The third energy level (n=3) has three subshells and nine orbitals.
- 3 The 3d subshell has five orbitals that have the same energy as each other in an isolated atom.

w/15/qp11

1s, 2s, 2p⁶, 3s¹
 12 1s, 2s, 2p⁶, 3s²

31 Which statements about the atoms ²³Na and ²⁴Mg are correct?

- 1 They have the same number of filled electron orbitals. ~~X~~
- 2** They have the same number of neutrons. ✓
- 3** They are both reducing agents. / oxidised, lose e⁻

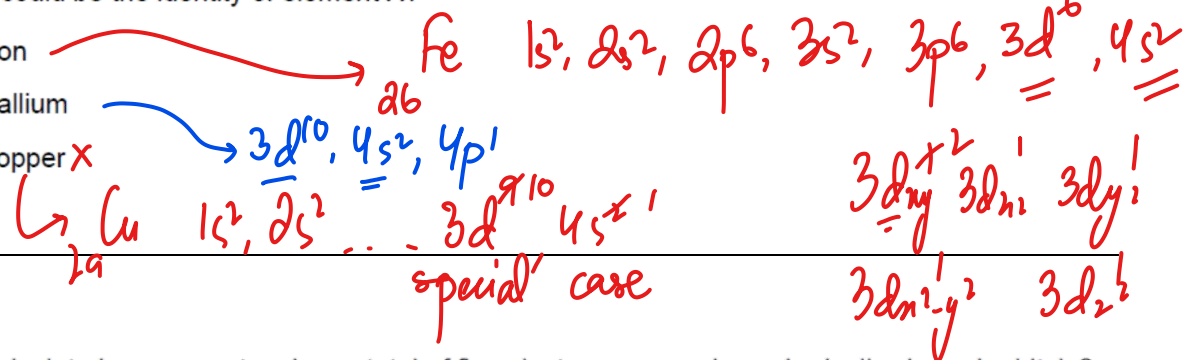
s/17/qp13

↳ metals like to lose e⁻

31 An isolated gaseous atom of element X has paired electrons in at least one of its 3d orbitals and has a filled 4s subshell.

What could be the identity of element X?

- ✓ 1 iron
- ✓ 2 gallium
- X 3 copper



s/17/qp12

5 Which isolated gaseous atom has a total of five electrons occupying spherically shaped orbitals?

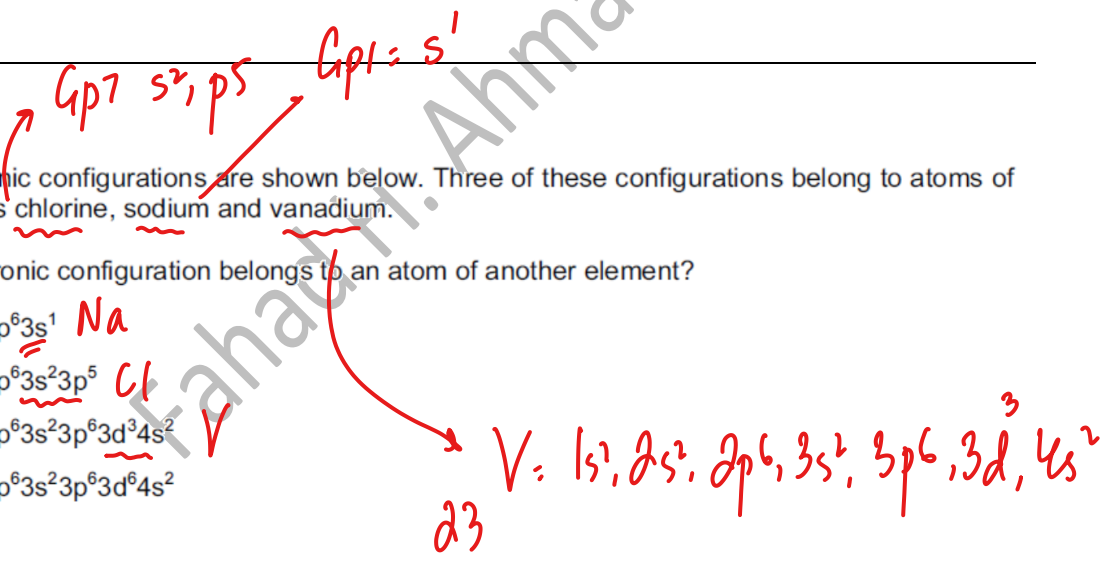
- A boron $1s^2, 2s^2, 2p^1$
- B fluorine $1s^2, 2s^2, 2p^5$
- ✓ C sodium $1s^2, 2s^2, 2p^6, 3s^1$
- D potassium

Handwritten note: spherically shaped orbitals → s

s/16/qp13

2 Four electronic configurations are shown below. Three of these configurations belong to atoms of the elements chlorine, sodium and vanadium.

- A $1s^2 2s^2 2p^6 3s^1$ Na
- B $1s^2 2s^2 2p^6 3s^2 3p^5$ Cl
- C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ V
- ✓ D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$



s/16/qp12

2 The electronic configuration of the two outermost shells of an atom is $3s^2 3p^6 3d^5 4s^2$.

What is this atom?

- ✓ A manganese
- B phosphorus s^2, p^3 X
- C strontium s^2 X
- D vanadium

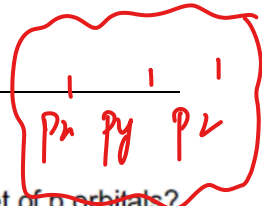
m/18/qp12

1 Which ion has the same electronic configuration as Cl^- ?

- A F^- B P^+ C Sc^{3+} D Si^{4+}

m/17/qp12

17
18e
Same no. of e^-



5 Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

- A C^- B N C N^- D O^+

s/04/qp1

$1s^2, 2s^2, 2p^2$ $1s^2, 2s^2, 2p^2$ $1s^2, 2s^2, 2p^3$ $1s^2, 2s^2, 2p^4$

4 What is the order of increasing energy of the listed orbitals in the atom of titanium?

- A 3s 3p 3d 4s
B 3s 3p 4s 3d
C 3s 4s 3p 3d
D 4s 3s 3p 3d

s/04/qp1

3 Gallium nitride, GaN, could revolutionise the design of electric light bulbs because only a small length used as a filament gives excellent light at low cost.

Gallium nitride is an ionic compound containing the Ga^{3+} ion.

What is the electron arrangement of the nitrogen ion in gallium nitride?

- A $1s^2 2s^2$
B $1s^2 2s^2 2p^3$
C $1s^2 2s^2 2p^4$
D $1s^2 2s^2 2p^6$

s/06/qp1

-3
 $7\text{N } 10e$
 $1s^2, 2s^2, 2p^6$

13 In which pair is the radius of the second atom greater than that of the first atom?

- A Na, Mg B Sr, Ca C P, N D Cl, Br

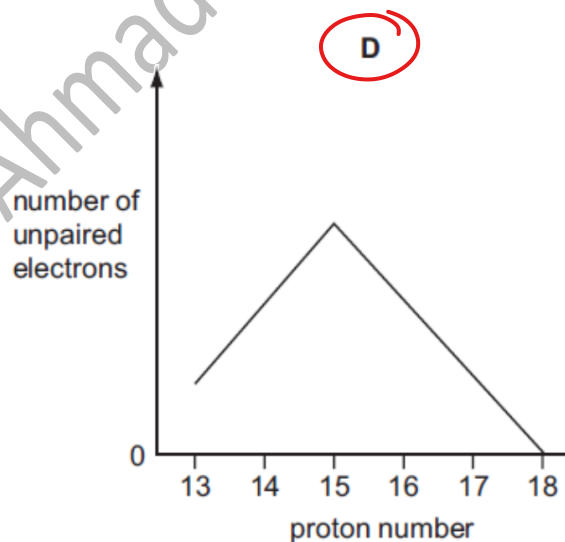
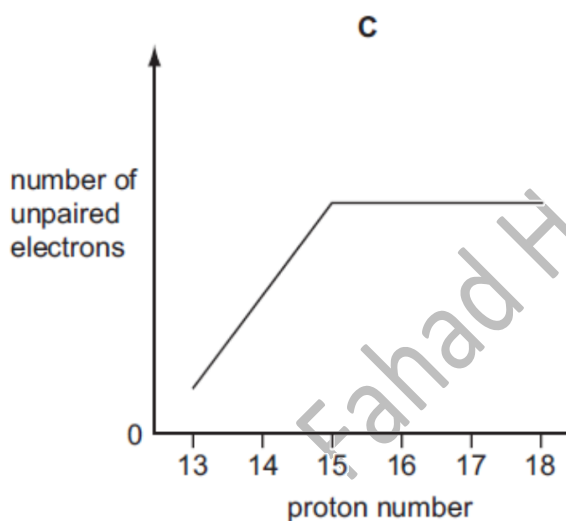
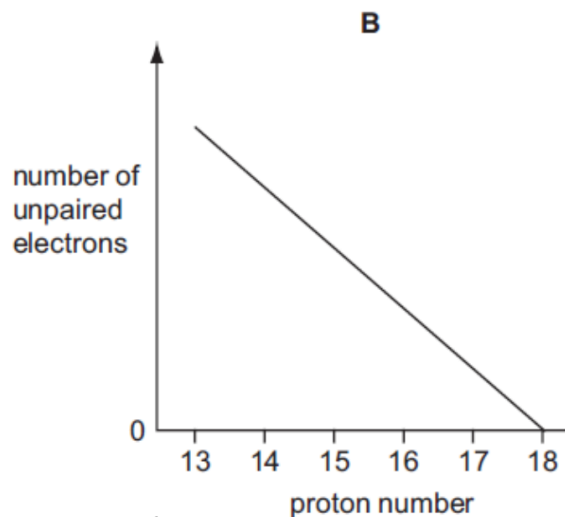
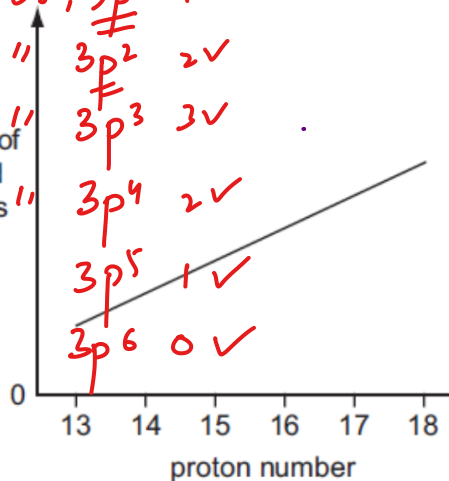
s/06/qp1

Br has more shells than Cl.

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

Which graph represents the number of unpaired p orbital electrons for atoms with proton numbers 13 to 18?

13e	$1s^2, 2s^2, 2p^6, 3s^2, 3p^1$	1 ✓	A
14e	" " " "	$3p^2$ 2 ✓	
15e	" " " "	$3p^3$ 3 ✓	
16e	" " " "	$3p^4$ 2 ✓	
17e	" " " "	$3p^5$ 1 ✓	
18e	" " " "	$3p^6$ 0 ✓	



s/09/qp1

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

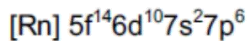
What could be the proton number of an element that has three unpaired electrons in each of its atoms?

- A 5 B 13 C 15 D 21

s/10/qp11

P

13 In 1999, researchers working in the USA believed that they had made a new element and that it had the following electronic configuration.



In which Group of the Periodic Table would you expect to find this element?

A II

B IV

C VI

D 0

s/11/qp12

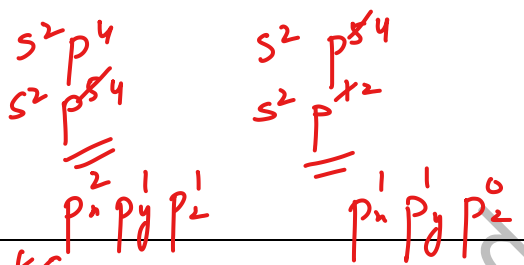
32 Use of the Data Booklet is relevant to this question.

In which pairs do both species have the same number of unpaired p electrons?

✓ 1 8O and Cl^+

✓ 2 F^+ and Ga^-

✗ 3 P and Ne^+



s/12/qp11

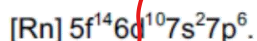
5 An atom has eight electrons.

Which diagram shows the electronic configuration of this atom in its lowest energy state?



w/04/qp1

13 In 1999, researchers working in the USA believed that they had made a new element and that it had the following electronic structure.



In which group of the Periodic Table would you expect to find this element?

A II

B IV

C VI

D 0

w/05/qp1

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

The electronic structures of s^2 calcium, s^2p^6 krypton, s^2p^3 phosphorus and an element X are shown.

Which electronic structure is that of element X?

- A $1s^2 2s^2 2p^6 3s^2 3p^3$ P
- B $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ Ca
- C** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$
- D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ Kr

w/06/qp1

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

In forming ionic compounds, elements generally form an ion with the electronic structure of a noble gas.

Which ion does not have a noble gas electronic structure?

- A I^-
- B Rb^+
- C** Sn^{2+}
- D Sr^{2+}

w/07/qp1

3 In which pair do both atoms have one electron only in an s orbital in their ground states?

- A Ca, Sc s^2, d^1
- B Cu, Be $4s^1, s^2$
- C H, He s^1, s^2
- D** Li, Cr s^1, s^1

w/08/qp1

2 A simple ion X^+ contains eight protons.

What is the electronic configuration of X^+ ?

- A $1s^2 2s^1 2p^6$
- B** $1s^2 2s^2 2p^3$
- C $1s^2 2s^2 2p^5$
- D $1s^2 2s^2 2p^7$

w/10/qp11

3 Which element has an equal number of electron pairs and of unpaired electrons within orbitals of principal quantum number 2?

- A beryllium s^2
- B carbon $s^2 p^2$ $\begin{matrix} s^2 & p_x^1 & p_y^1 & p_z^0 \\ \underline{\underline{=}} & \underline{\underline{=}} & \underline{\underline{=}} & \end{matrix}$
- C nitrogen $s^2 p^3$ $\begin{matrix} s^2 & p_x^1 & p_y^1 & p_z^1 \\ \underline{\underline{=}} & \underline{\underline{=}} & \underline{\underline{=}} & \underline{\underline{=}} \end{matrix}$
- D** oxygen $s^2 p^4$ $\begin{matrix} s^2 & p_x^2 & p_y^1 & p_z^1 \\ \underline{\underline{=}} & \underline{\underline{=}} & \underline{\underline{=}} & \underline{\underline{=}} \end{matrix}$

w/11/qp11

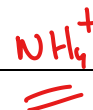
32 Use of the Data Booklet is relevant to this question.

$s^2 p^2$ Carbon and nitrogen are adjacent in the Periodic Table.

Which properties do they both have?

- 1 There is an empty 2p orbital in one atom of the element. \times
- 2 The principal quantum number of the highest occupied orbital is 2. \checkmark
- 3 They form compounds in which their atoms form bonds with four other atoms. \checkmark

w/13/qp11



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

Which ions contain one or more unpaired electrons?

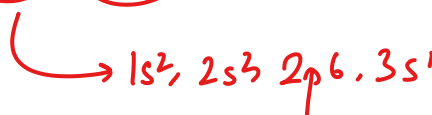
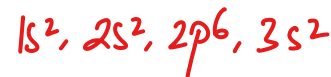
- 1 Cu^{2+} \checkmark ... $3d^9, 4s^1$
- 2 Mn^{3+} \checkmark ... $3d^5, 4s^2$
- 3 V^{3+} \checkmark ... $3d^3, 4s^2$

w/14/qp11

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

Which statements are correct when referring to the atoms ^{23}Na and ^{24}Mg ?

- \times 1 They have the same number of full electron orbitals.
- 2 They have the same number of neutrons. \checkmark
- 3 They are both reducing agents. \checkmark



\hookrightarrow metals like to lose e^- / get oxidize

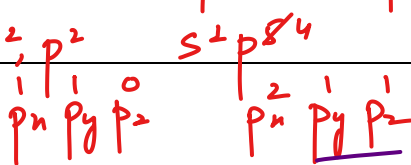
s/13/qp13

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

In which pairs do both species have the same number of unpaired p electrons?

- 1 Al^{2-} and O^+ \checkmark $s^2 p^3$ s^2, p^3
- 2 N and Cl^{2+} \checkmark $s^2 p^3$ $s^2 p^3$
- 3 C and Cl^+ \checkmark $s^2 p^2$ $s^2 p^3$

s/13/qp12



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

Atoms of element X have six unpaired electrons.

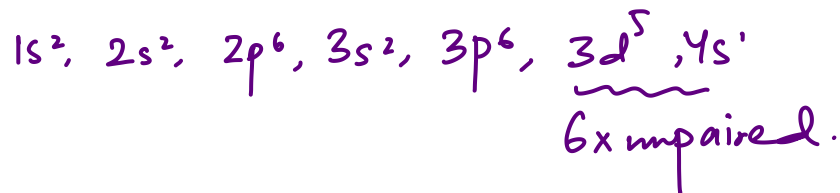
What could be element X?

A carbon

B chromium

C iron

D selenium



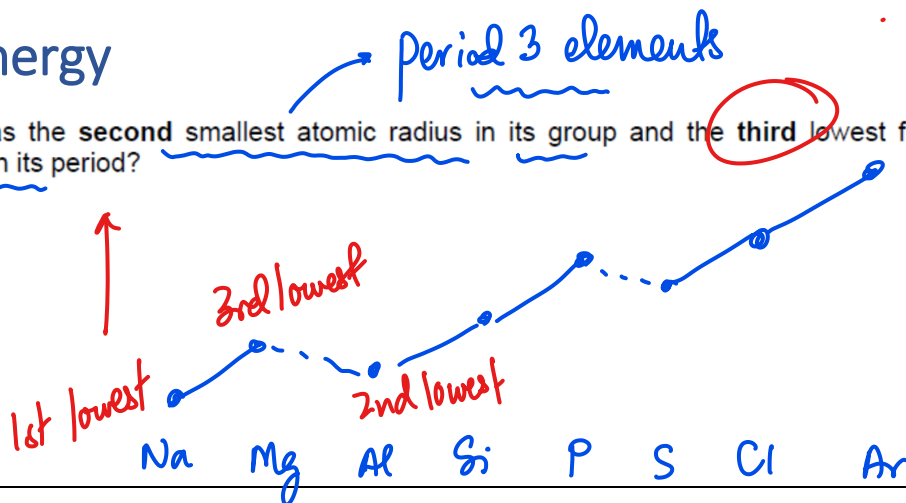
s/14/qp11

Fahad H. Ahmad

Ionization Energy

13 Which element has the second smallest atomic radius in its group and the third lowest first ionisation energy in its period?

- A boron
- B calcium
- C magnesium**
- D sodium



s/18/qp11

10 Element X has a higher first ionisation energy than element Y.

Two students state what they believe is one factor that helps to explain this.

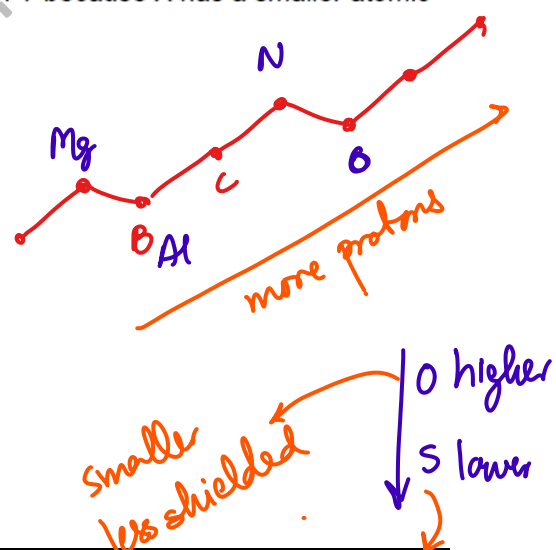
- ✓ student 1 "X has a higher first ionisation energy than Y because an atom of X has more protons in its nucleus than an atom of Y."
- ✓ student 2 "X has a higher first ionisation energy than Y because X has a smaller atomic radius than Y."

Only one of the two students is correct.

What could X and Y be?

	higher X	Y
A	carbon ✓	boron
B	magnesium ✓	aluminium
X	oxygen lower	nitrogen
D	oxygen ✓	sulfur

✓ S₂ S₁ ✓
 X S₂ S₁ X
 ✓ S₂ S₁ X



s/18/qp11

31 The definitions of many chemical terms can be illustrated by chemical equations.

Which terms can be illustrated by an equation that includes the formation of a positive ion?

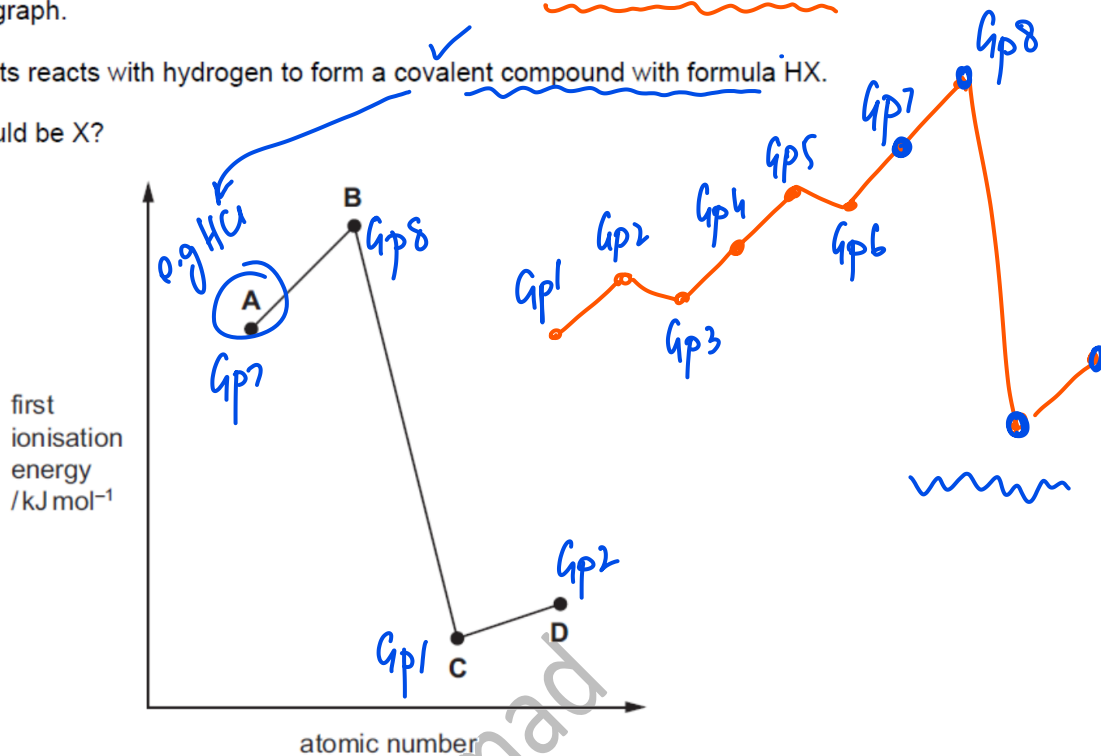
- 1** first ionisation energy ✓ $X(g) \rightarrow X^+(g) + e$
- 2** heterolytic fission of a covalent bond ✓ $=$
- 3 enthalpy change of atomisation

w/17/qp11

- 2 The relative first ionisation energies of four elements with consecutive atomic numbers below 20 are shown on the graph.

One of the elements reacts with hydrogen to form a covalent compound with formula HX .

Which element could be X?



w/17/qp11

- 33 X is an element that has

- its outer electrons in the 4th principal quantum shell,
- a higher 1st ionisation energy than calcium.

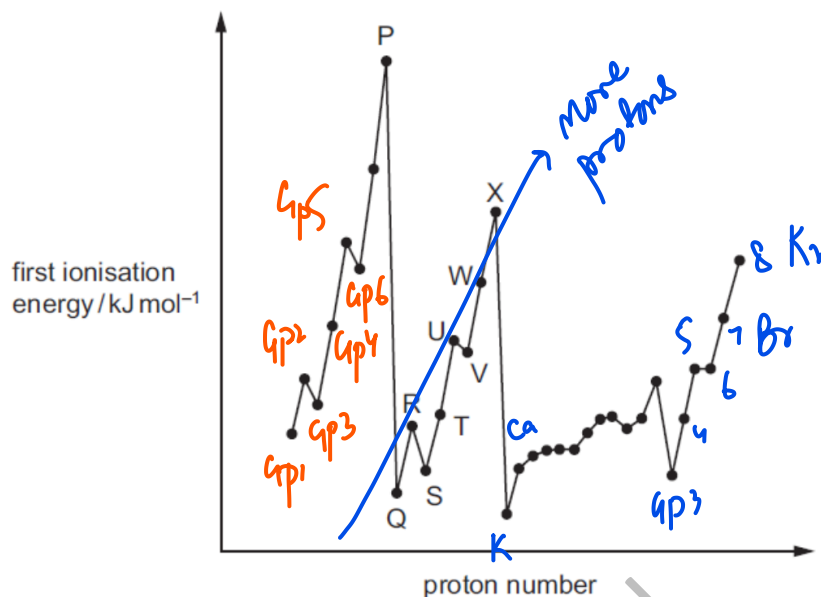
→ period 4

What could be the identity of X?

- 1 bromine ✓
- 2 krypton ✓
- 3 xenon *not in period 4*

w/16/qp12

- 12 The graph below shows the variation of the first ionisation energy with proton number for some elements. The letters used are not the usual symbols for the elements.



Which statement about the elements is correct?

- A P and X are in the same period in the Periodic Table. *X different*
- B The general increase from Q to X is due to increasing atomic radius.
- C The small decrease from R to S is due to decreased shielding.
- D** The small decrease from U to V is due to repulsion between paired electrons. *dip at Gp6*

w/16/qp12

- 14 The properties of chlorine, bromine and their compounds are compared.

Which property is smaller for chlorine than for bromine?

- A bond strength of the hydrogen-halide bond
- B first ionisation energy *X*
- C solubility of the silver halide in $\text{NH}_3(\text{aq})$
- D** strength of the van der Waals' forces between molecules of the element

w/16/qp11

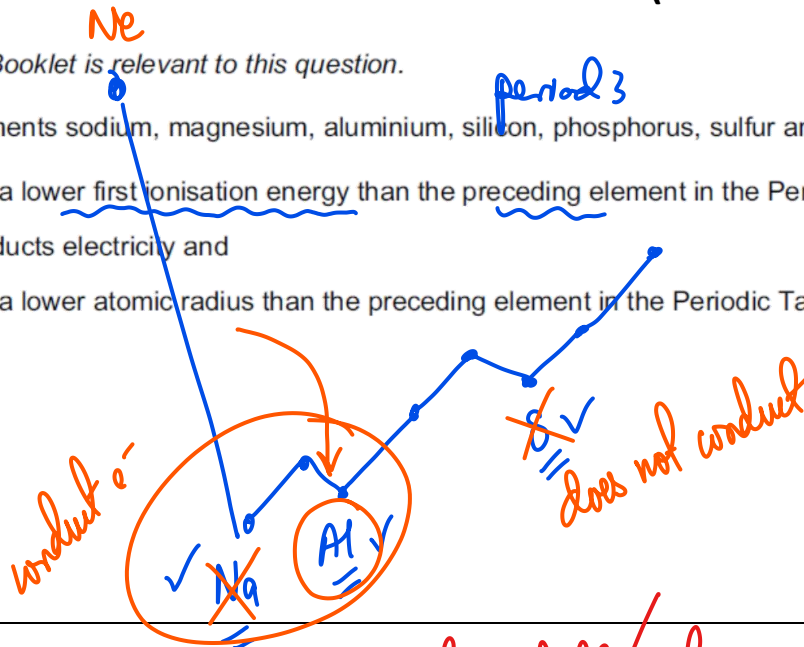
Cl | *1.8*
higher ✓
Br ↓

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

Which of the elements sodium, magnesium, aluminium, silicon, phosphorus, sulfur and chlorine

- has a lower first ionisation energy than the preceding element in the Periodic Table,
- conducts electricity and
- has a lower atomic radius than the preceding element in the Periodic Table?

- A** aluminium
- B magnesium
- C phosphorus
- D sulfur



w/15/qp13

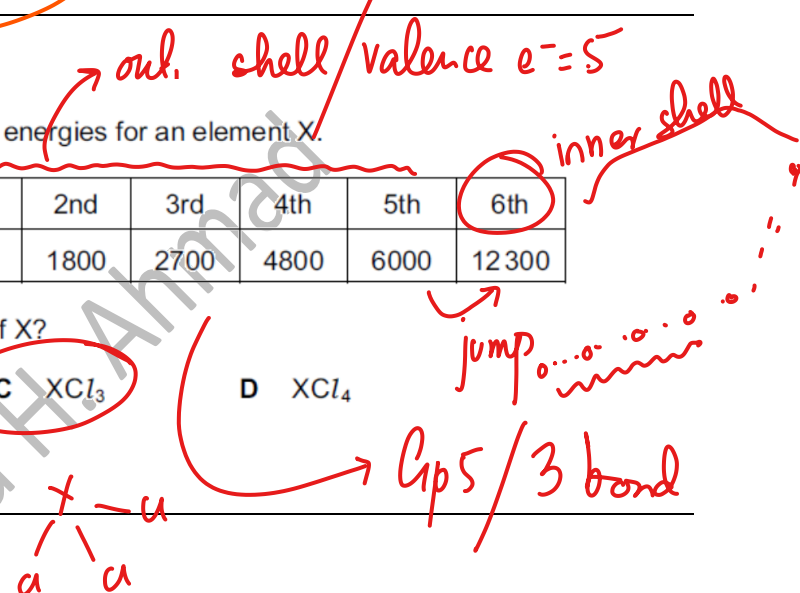
1 The table gives the successive ionisation energies for an element X.

	1st	2nd	3rd	4th	5th	6th
ionisation energy / kJ mol ⁻¹	950	1800	2700	4800	6000	12300

What could be the formula of a chloride of X?

- A XCl
- B XCl₂
- C XCl₃**
- D XCl₄

w/15/qp13



32 Which of the following influence the size of the ionisation energy of an atom?

- 1 the amount of shielding by the inner electrons ✓
- 2 the charge on the nucleus ✓
- 3 the distance between the outer electrons and the nucleus ✓

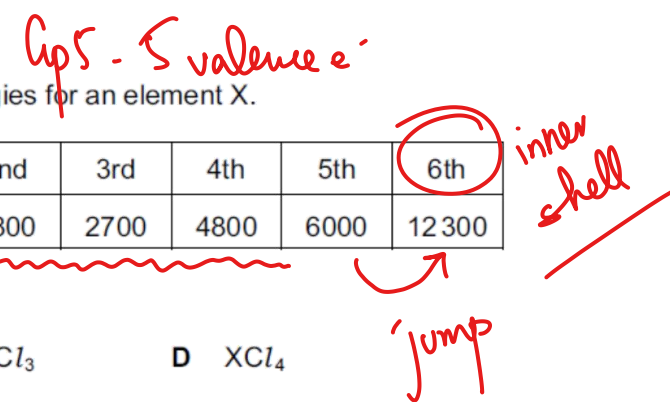
w/15/qp12

1 The table gives the successive ionisation energies for an element X.

	1st	2nd	3rd	4th	5th	6th
ionisation energy / kJ mol ⁻¹	950	1800	2700	4800	6000	12300

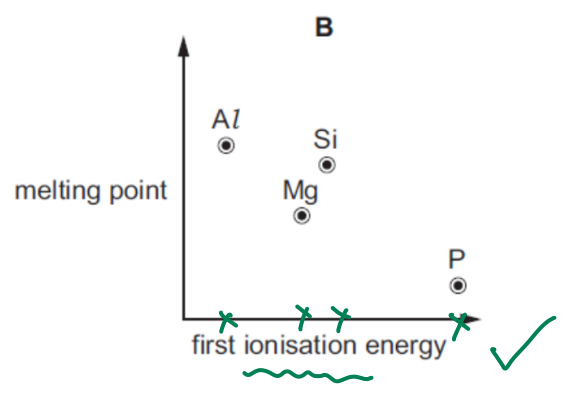
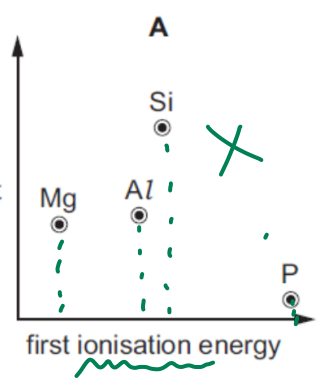
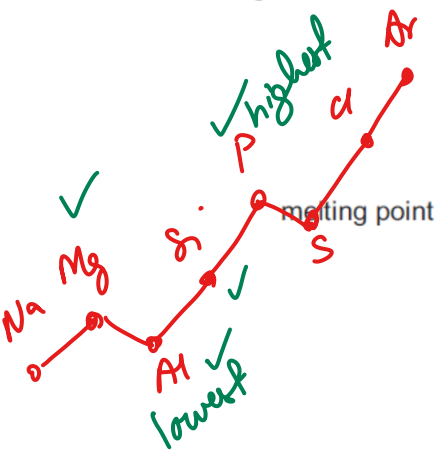
What could be the formula of a chloride of X?

- A XCl
- B XCl₂
- C XCl₃**
- D XCl₄

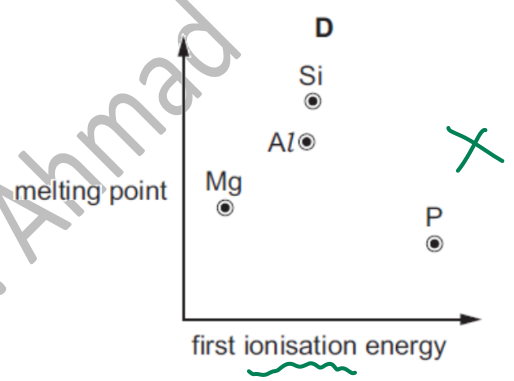
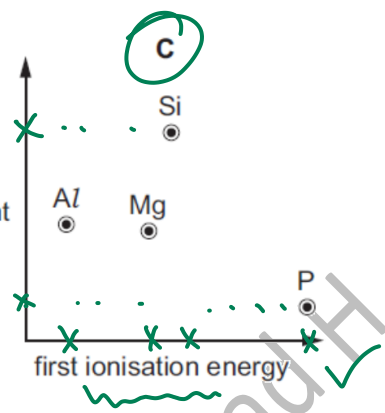


w/15/qp11

13 Which graph correctly shows the relative melting points of the elements Mg, Al, Si and P plotted against their relative first ionisation energies?



Si - very high MP
P - non metal

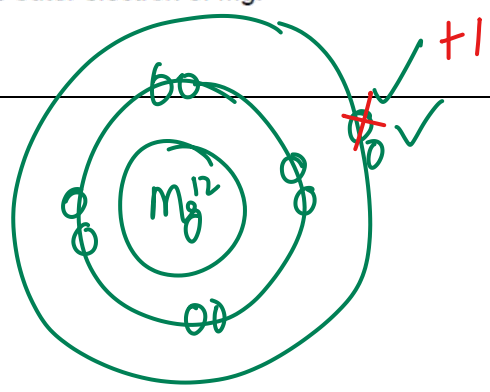
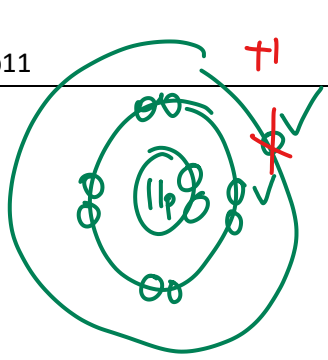


s/17/qp13

12 Why is the second ionisation energy of sodium larger than the second ionisation energy of magnesium?

- A The attraction between the nucleus and the outer electron is greater in Na^+ than in Mg^+ .
- B The nuclear charge of Na^+ is greater than that of Mg^+ .
- C The outer electron of Na^+ is more shielded than the outer electron of Mg^+ .
- D The outer electron of Na is in the same orbital as the outer electron of Mg.

s/17/qp11



4 Which property of an atom does **not** affect its first ionisation energy?

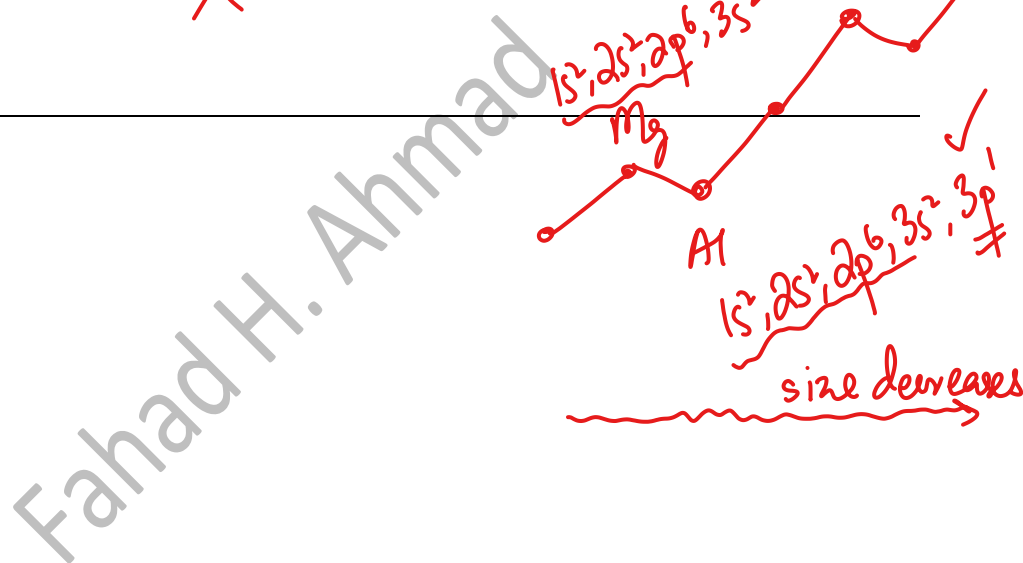
- A the atomic radius ✓
- B the number of electron shells ✓
- C** the number of neutrons ✗
- D the number of protons ✓

s/17/qp11

35 Why is the first ionisation energy of aluminium less than that of magnesium?

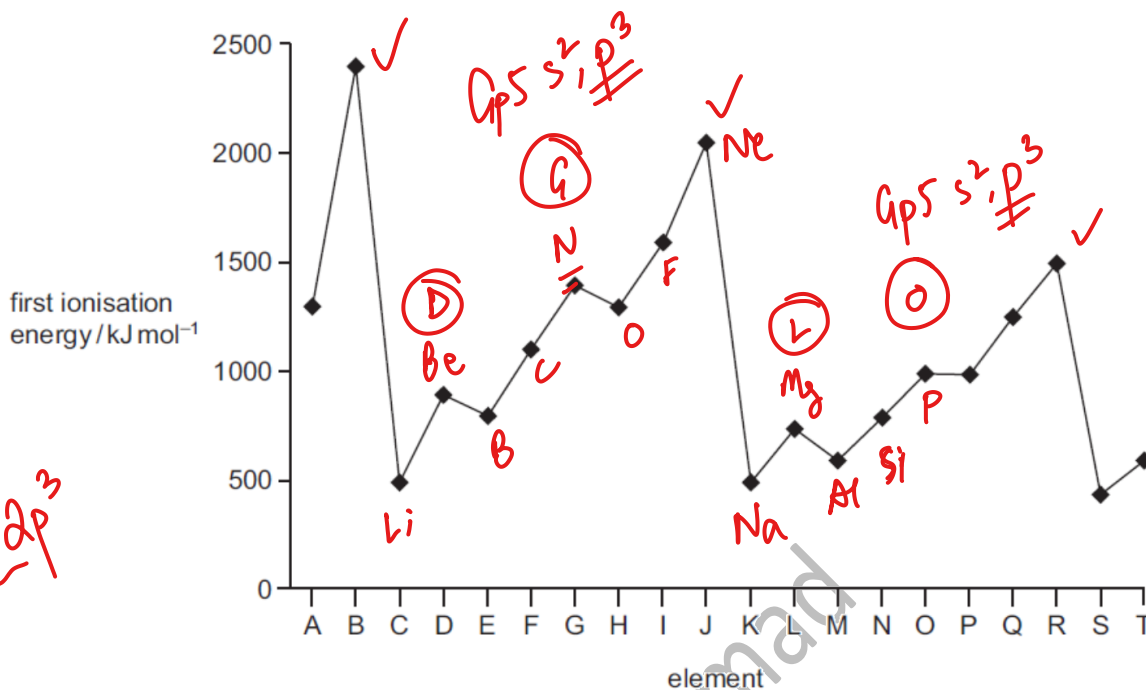
- 1 The outer electron in the aluminium atom is more shielded from the nuclear charge. ✓
- 2 The outer electron in the aluminium atom is in a higher energy orbital. ✓
- 3 The outer electron in the aluminium atom is further from the nucleus. ✗

s/16/qp13



35 The first ionisation energies of twenty successive elements in the Periodic Table are represented in the graph.

The letters given are not the normal symbols for these elements.



Which statements about this graph are correct?

- 1 Elements B, J and R are in Group 18 of the Periodic Table. ✓
- 2 Atoms of elements D and L contain two electrons in their outer shells. ✓
- 3 Atoms of elements G and O contain a half-filled p subshell. ✓

s/16/qp12

3 Elements X and Y are in the same group of the Periodic Table.

The table shows the first six ionisation energies of X and Y in kJ mol^{-1} .

	1st	2nd	3rd	4th	5th	6th
X	800	1600	2400	4300	5400	<u>10400</u>
Y	1000	1800	2700	4800	6000	12300

Handwritten notes: 'Gp5' with an arrow pointing to the 5th ionisation energy column; 'inner shell' with an arrow pointing to the 6th ionisation energy column.

What could be the identities of X and Y?

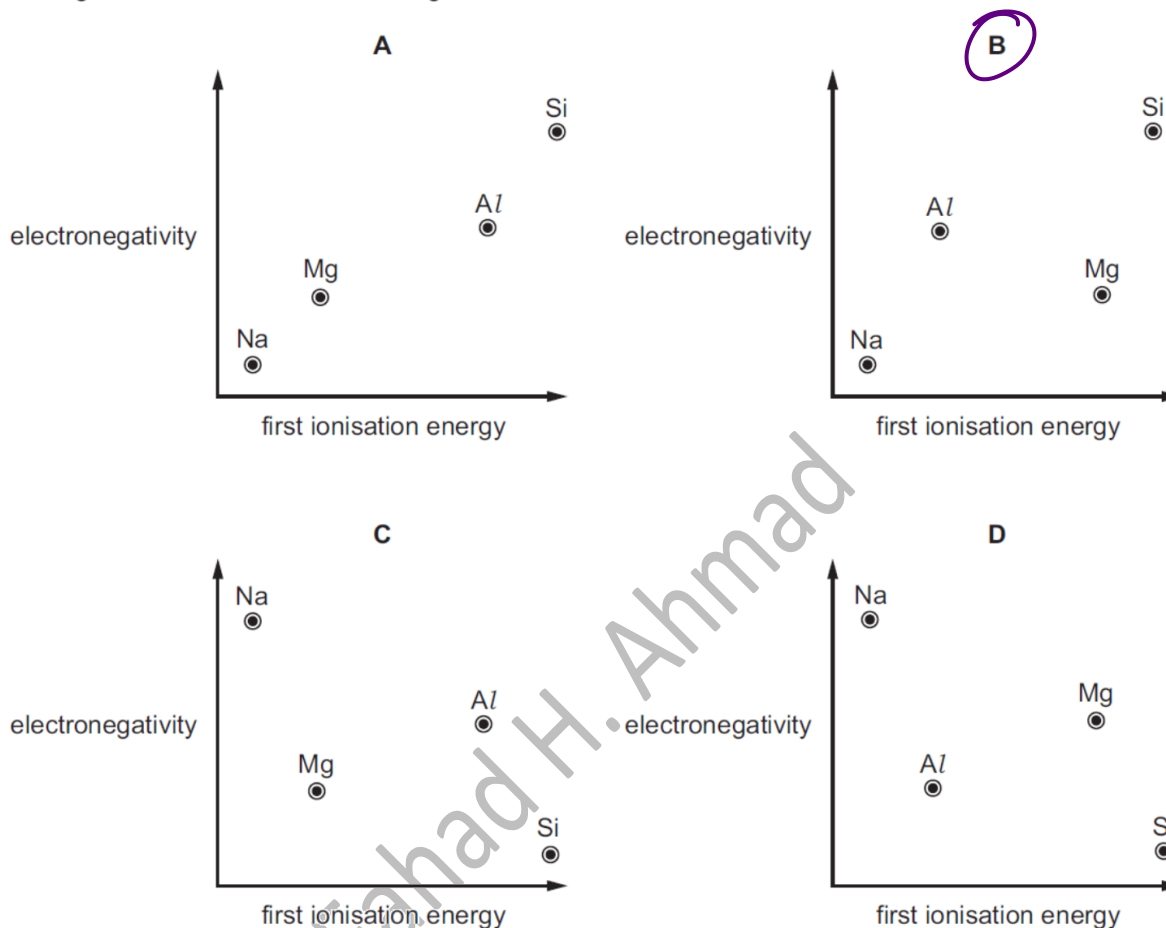
X Y are Gp5

	X	Y
A	antimony, Sb	arsenic, As
B	arsenic, As	antimony, Sb
C	selenium, Se	tellurium, Te
D	tellurium, Te	selenium, Se

s/16/qp12

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

Which diagram correctly shows the electronegativity of the elements Na, Mg, Al and Si plotted against their first ionisation energies?

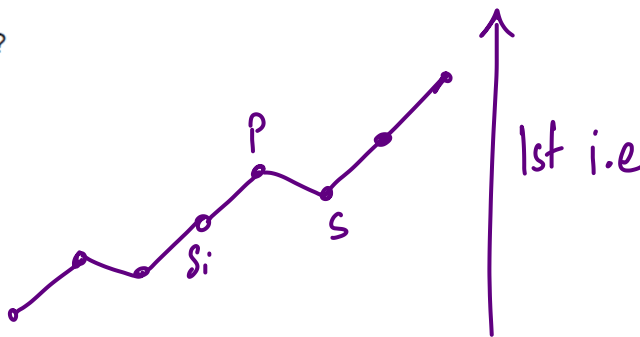


s/15/qp12

12 Consecutive elements X, Y and Z are in Period 3 of the Periodic Table. Element Y has the highest first ionisation energy and the lowest melting point of these three elements.

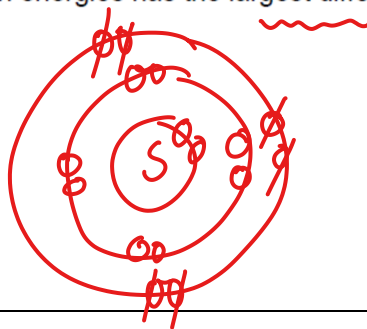
What are the identities of X, Y and Z?

- A sodium, magnesium, aluminium
- B magnesium, aluminium, silicon
- C aluminium, silicon, phosphorus
- D silicon, phosphorus, sulfur**



m/16/qp12

- 2 For the element sulfur, which pair of ionisation energies has the largest difference between them?
- A third and fourth ionisation energies
 B fourth and fifth ionisation energies
 C fifth and sixth ionisation energies
 D sixth and seventh ionisation energies



m/16/qp12

- 4 The successive ionisation energies, in kJ mol^{-1} , of an element X are given below.

870 1800 3000 3600 5800 7000 13200

What is X?

A ${}_{33}\text{As}$ B ${}_{40}\text{Zr}$ C ${}_{52}\text{Te}$ D ${}_{53}\text{I}$

s/03/qp1

- 3 The first six ionisation energies of four elements, A to D, are given.

Which element is most likely to be in Group IV of the Periodic Table?

ionisation energy/ kJ mol^{-1}	1st	2nd	3rd	4th	5th	6th
A	494	4560	6940	9540	13400	16600
B	736	1450	7740	10500	13600	18000
C	1090	2350	4610	6220	37800	47000
D	1400	2860	4590	7480	9400	53200

s/06/qp1

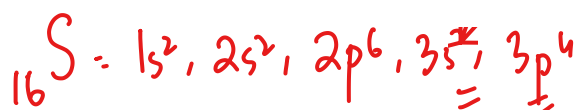
- 3 The first seven ionisation energies of an element between lithium and neon in the Periodic Table are as follows.

1310 3390 5320 7450 11 000 13 300 71 000 kJ mol^{-1}

What is the outer electronic configuration of the element?

A $2s^2$ B $2s^2 2p^1$ C $2s^2 2p^4$ D $2s^2 2p^6$

s/09/qp1

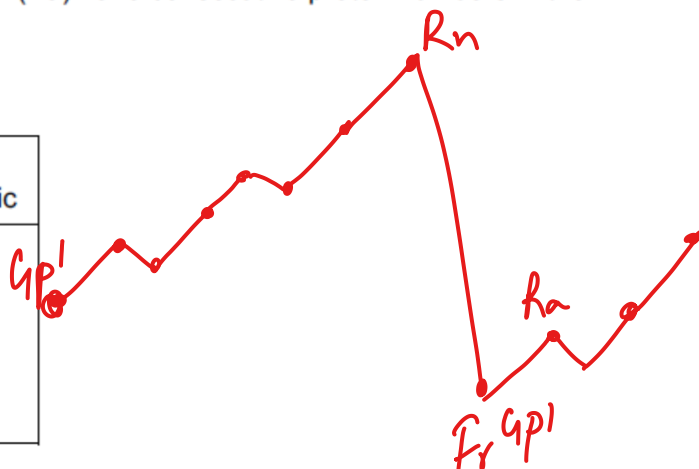


2 Use of the Data Booklet is relevant to this question.

The elements radon (Rn), francium (Fr) and radium (Ra) have consecutive proton numbers in the Periodic Table.

What is the order of their first ionisation energies?

	least endothermic	→	most endothermic
A	Fr		Rn
B	Fr		Ra
C	Ra		Rn
D	Rn		Fr



s/10/qp11

16 Consecutive elements X, Y, Z are in the third period of the Periodic Table. Element Y has the highest first ionisation energy and the lowest melting point.

What could be the identities of X, Y and Z?

- A aluminium, silicon, phosphorus
- B magnesium, aluminium, silicon
- C silicon, phosphorus, sulfur
- D sodium, magnesium, aluminium

s/10/qp11

1 Which equation represents the second ionisation energy of an element X?

- A $X(g) \rightarrow X^{2+}(g) + 2e^{-}$
- B** $X^{+}(g) \rightarrow X^{2+}(g) + e^{-}$
- C $X(g) + 2e^{-} \rightarrow X^{2-}(g)$
- D $X^{-}(g) + e^{-} \rightarrow X^{2-}(g)$

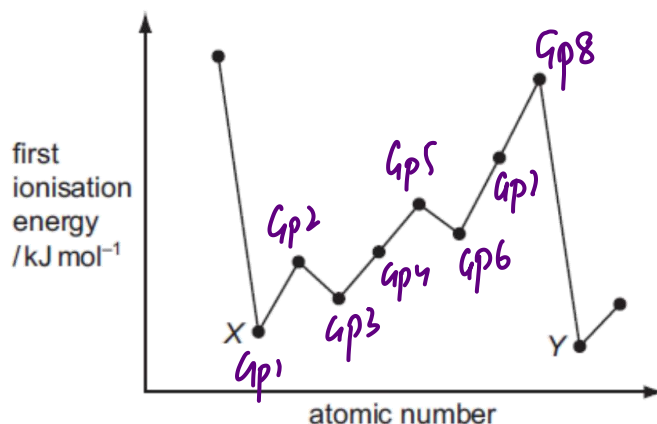
s/11/qp11

5 Which factor helps to explain why the first ionisation energies of the Group I elements decrease from lithium to sodium to potassium to rubidium?

- A The nuclear charge of the elements increases.
- B The outer electron is in an 's' subshell.
- C The repulsion between spin-paired electrons increases.
- D** The shielding effect of the inner shells increases.

s/11/qp11

15 The diagram shows the first ionisation energies of 11 consecutive elements.



Which type of elements are labelled X and Y?

- A Group I metals
- B Group II metals
- C halogens
- D noble gases

s/11/qp12

4 The value of the second ionisation energy of calcium is 1150 kJ mol^{-1} .

Which equation correctly represents this statement?

- A $\text{Ca(g)} \rightarrow \text{Ca}^{2+}(\text{g}) + 2\text{e}^-$; $\Delta H^\ominus = +1150 \text{ kJ mol}^{-1}$
- B $\text{Ca}^+(\text{g}) \rightarrow \text{Ca}^{2+}(\text{g}) + \text{e}^-$; $\Delta H^\ominus = +1150 \text{ kJ mol}^{-1}$ ✓
- C $\text{Ca}^+(\text{g}) \rightarrow \text{Ca}^{2+}(\text{g}) + \text{e}^-$; $\Delta H^\ominus = -1150 \text{ kJ mol}^{-1}$
- D $\text{Ca(g)} \rightarrow \text{Ca}^{2+}(\text{g}) + 2\text{e}^-$; $\Delta H^\ominus = -1150 \text{ kJ mol}^{-1}$

endo
=

s/12/qp11

8 The value of the third ionisation energy of aluminium is 2740 kJ mol^{-1} .

Which correctly represents this statement?

- A $\text{Al(g)} \rightarrow \text{Al}^{3+}(\text{g}) + 3\text{e}^-$ $\Delta H^\ominus = -2740 \text{ kJ mol}^{-1}$
- B $\text{Al}^{2+}(\text{g}) \rightarrow \text{Al}^{3+}(\text{g}) + \text{e}^-$ $\Delta H^\ominus = -2740 \text{ kJ mol}^{-1}$
- C $\text{Al(g)} \rightarrow \text{Al}^{3+}(\text{g}) + 3\text{e}^-$ $\Delta H^\ominus = +2740 \text{ kJ mol}^{-1}$
- D $\text{Al}^{2+}(\text{g}) \rightarrow \text{Al}^{3+}(\text{g}) + \text{e}^-$ $\Delta H^\ominus = +2740 \text{ kJ mol}^{-1}$

s/12/qp12

5 The table gives the successive ionisation energies for an element X.

	1st	2nd	3rd	4th	5th	6th
ionisation energy / kJ mol^{-1}	950	1800	2700	4800	6000	12300

What could be the formula of the chloride of X?

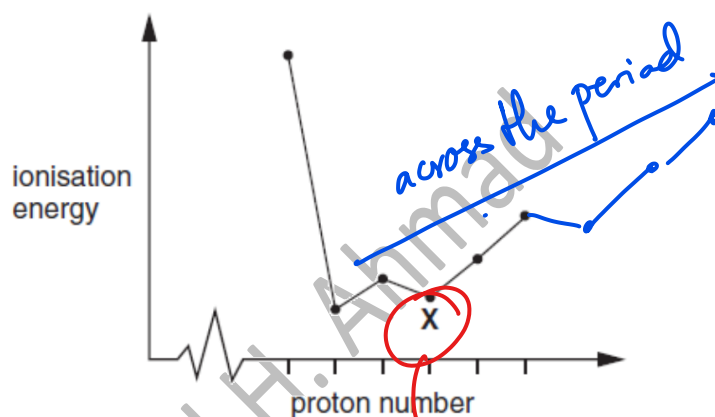
- A XCl B XCl_2 C XCl_3 D XCl_4

w/03/qp1

5 valence e^-

Grp 5 makes 3 bonds

13 The sketch below shows the variation of first ionisation energy with proton number for six elements of consecutive proton numbers between 1 and 18 (H to Ar).



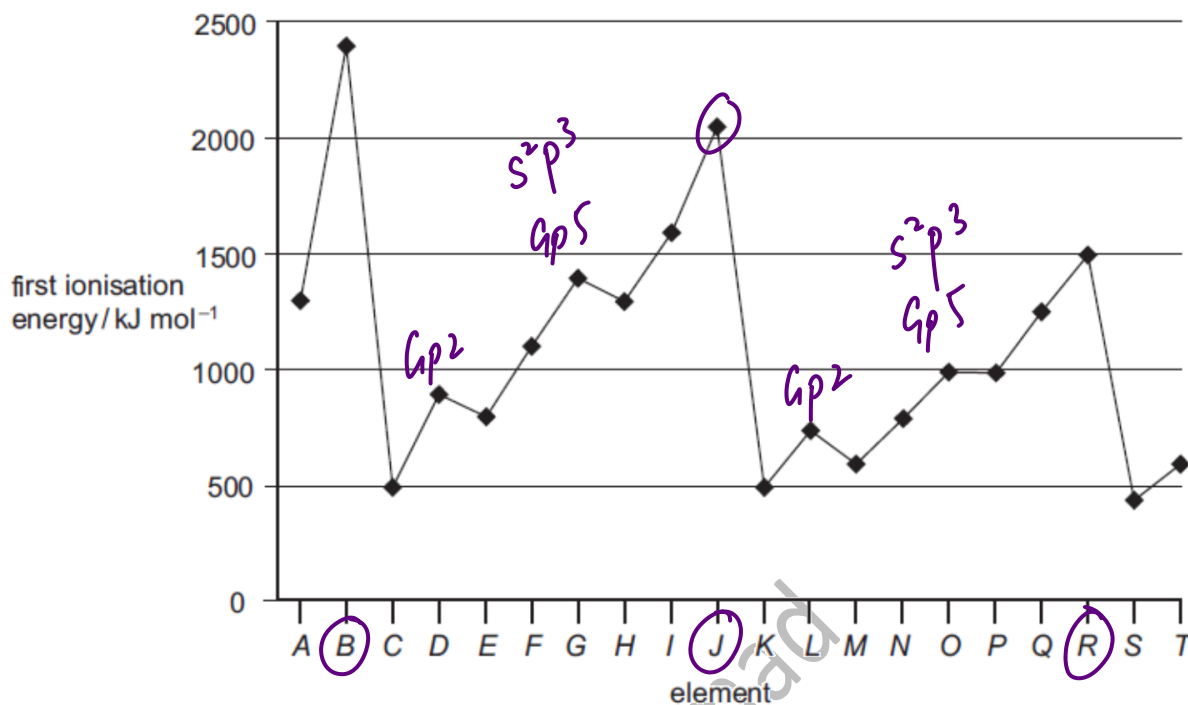
What is the identity of the element X?

- A Mg B Al C Si D P

w/03/qp1

Grp 3

34 The first ionisation energies of successive elements in the Periodic Table are represented in the graph.



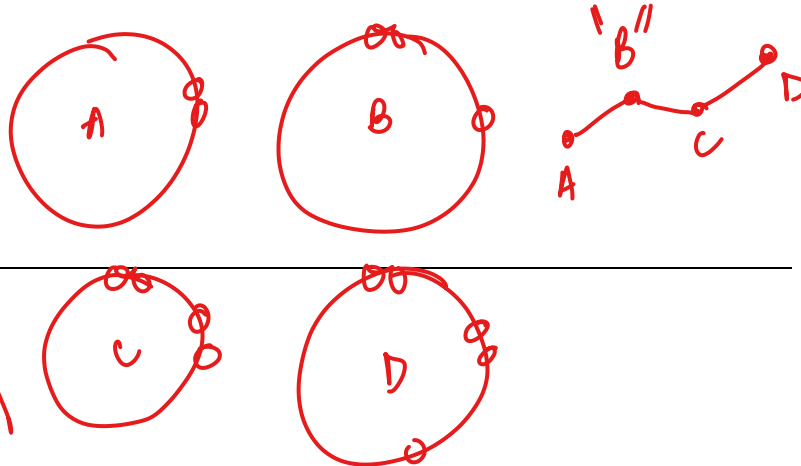
Which of these statements about this graph are correct?

- 1 Elements B, J and R are in Group 0 of the Periodic Table. ✓
- 2 Atoms of elements D and L contain 2 electrons in their outer shells. ✓
- 3 Atoms of elements G and O contain half-filled p orbitals. ✓

w/04/qp1

3 What is the electronic configuration of an element with a second ionisation energy higher than that of each of its neighbours in the Periodic Table?

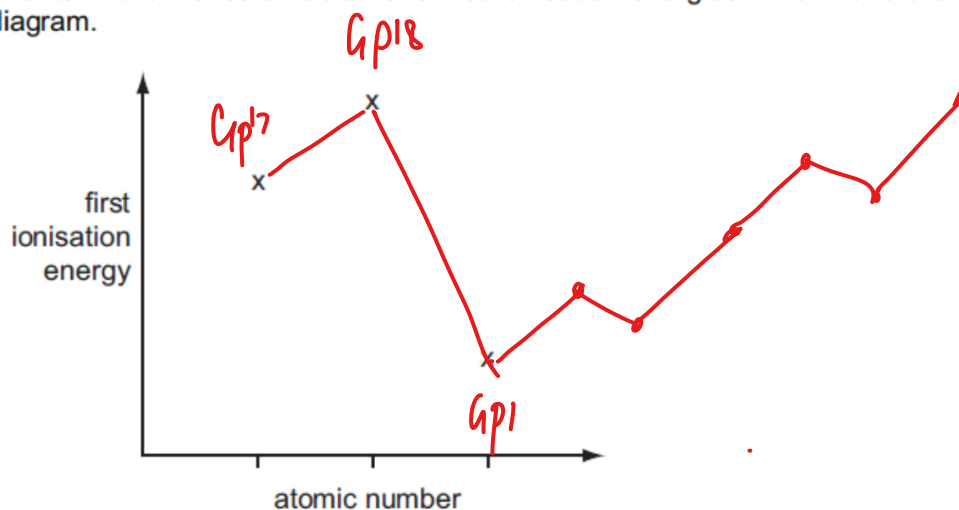
- A $1s^2 2s^2 2p^6 3s^1$
- B** $1s^2 2s^2 2p^6 3s^2 3p^1$
- C $1s^2 2s^2 2p^6 3s^2 3p^2$
- D $1s^2 2s^2 2p^6 3s^2 3p^2$



dip
3p is higher energy

w/05/qp1

- 2 Three successive elements in the Periodic Table have first ionisation energies which have the pattern shown in the diagram.



What could be the first element of this sequence?

A C

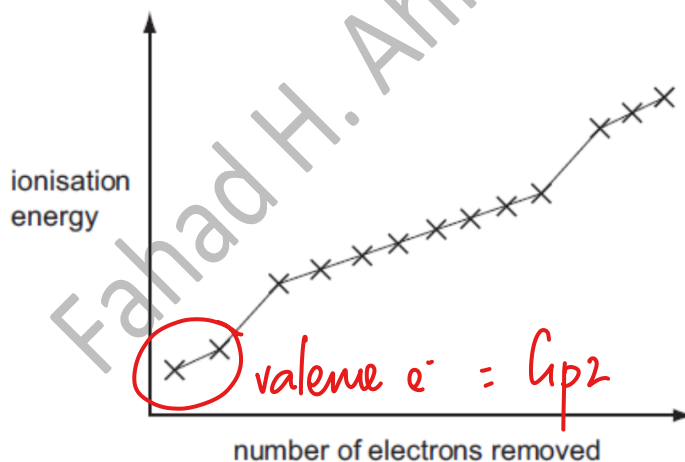
B N

C F

D Na

w/06/qp1

- 4 The graph shows the first thirteen ionisation energies for element X.



What can be deduced about element X from the graph?

A It is in the second period (Li to Ne) of the Periodic Table.

B It is a d-block element.

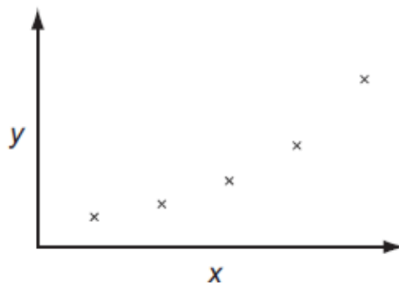
C It is in Group II of the Periodic Table.

D It is in Group III of the Periodic Table.

w/07/qp1

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

The sketch graph shows the variation of one physical or chemical property with another for the Group II elements.



What are the correct labels for the axes?

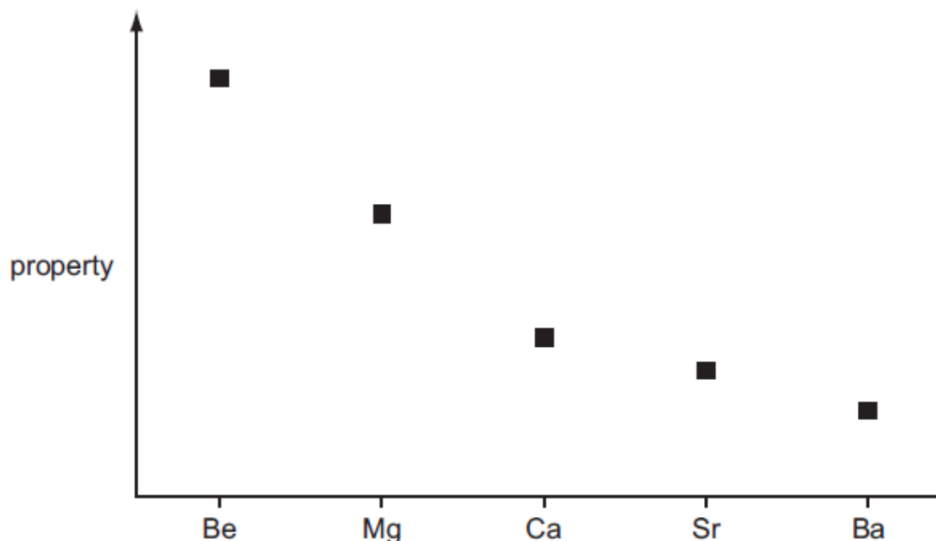
	x-axis	y-axis
A	atomic number	mass number
B	atomic number	melting point
C	first ionisation energy	atomic number
D	first ionisation energy	atomic radius

} i.e. should decrease

w/07/qp1

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

The graph represents the variation of a property of the Group II elements.

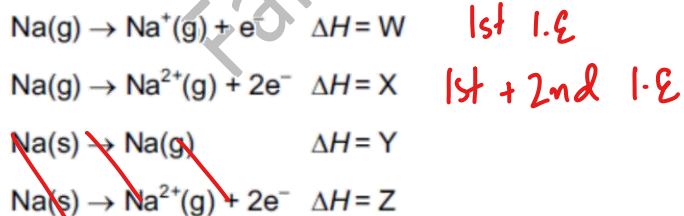


What is this property?

- A ionic radius
- B ionisation energy**
- C neutron/proton ratio
- D rate of reaction with water

w/09/qp11

3 Equations involving four enthalpy changes are shown.



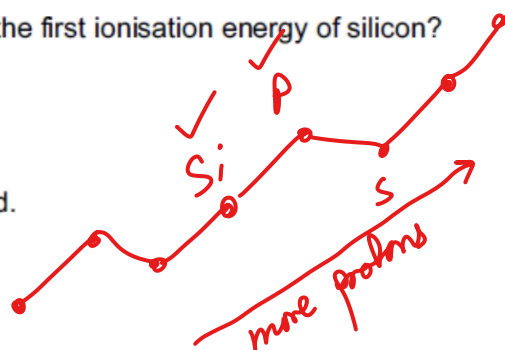
What is the second ionisation energy of sodium?

- A 2W
- B X - W**
- C Y - W
- D Z - Y

w/10/qp11

13 Why is the first ionisation energy of phosphorus greater than the first ionisation energy of silicon?

- A A phosphorus atom has one more proton in its nucleus.**
- B The atomic radius of a phosphorus atom is greater.
- C The outer electron in a phosphorus atom is more shielded.
- D The outer electron in a phosphorus atom is paired.



w/10/qp11

31 The definitions of many chemical terms can be illustrated by chemical equations.

Which terms can be illustrated by an equation that shows the formation of a positive ion?

- ① first ionisation energy $X(g) \rightarrow X^+(g) + 1e$
- ② heterolytic fission ✓
- 3 enthalpy change of atomisation ✗

w/11/qp11

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

From which particle is the removal of an electron the most difficult?

A $Cl^-(g)$
2, 8, 8

B $F^-(g)$ 9p
2, 8

C $K^+(g)$
2, 8, 8

D $Na^+(g)$ 11p
2, 8

smaller atom
more protons

w/11/qp12

7 The table gives the successive ionisation energies for an element X.

	1st	2nd	3rd	4th	5th	6th
ionisation energy / kJ mol^{-1}	950	1800	2700	4800	6000	12300

What could be the formula of the chloride of X?

A XC_l

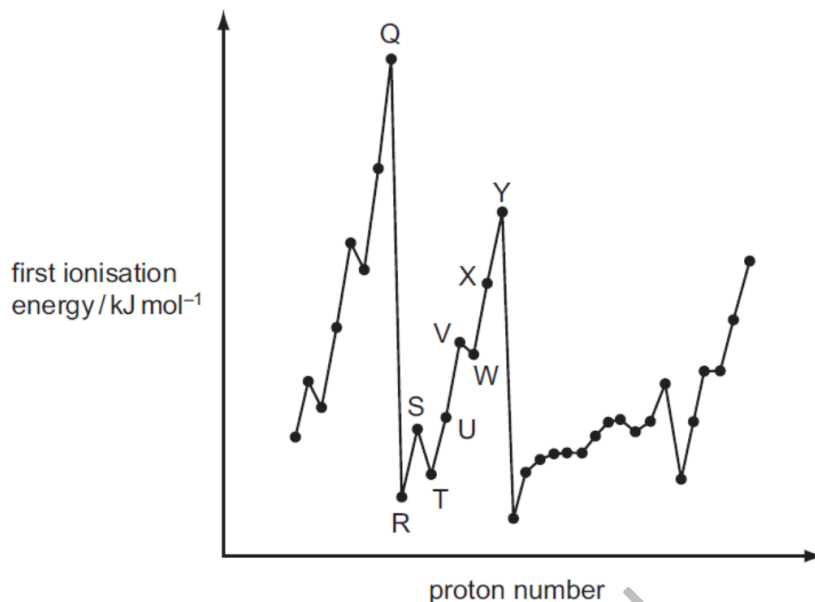
B XC_l_2

C XC_l_3

D XC_l_4

w/12/qp13

18 The graph below shows the variation of the first ionisation energy with the number of protons for some elements.



Which statement is correct?

- A Elements Q and Y are in the same period in the Periodic Table.
- B The general increase from elements R to Y is due to increasing atomic radius.
- C The small decrease between elements S and T is due to decreased shielding.
- D** The small decrease between elements V and W is due to repulsion between paired electrons.

w/13/qp13

dip at gp 6.

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

Element X forms X^- ions that can be oxidised to element X by acidified potassium manganate(VII).

gp 7

What could be the values of the first four ionisation energies of X?

	1st	2nd	3rd	4th
A	418	3070	4600	5860
B	577	1820	2740	11 600
C	590	1150	4940	6480
D	1010	1840	2040	4030

gp1
gp3
gp2
no jump, must be gp 7

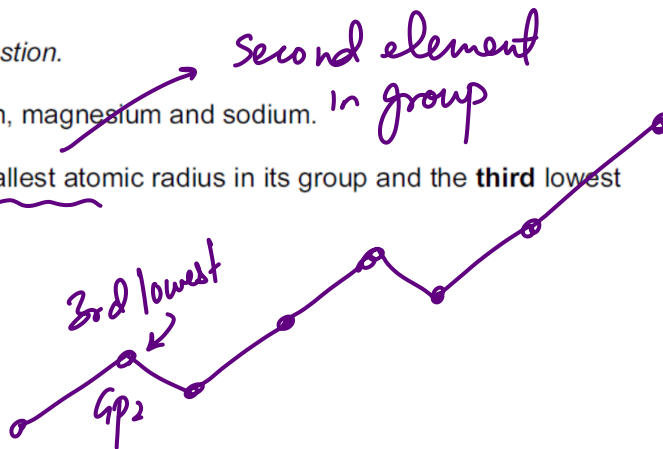
w/13/qp13

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

Sir Humphrey Davy discovered boron, calcium, magnesium and sodium.

Which of these elements has the **second** smallest atomic radius in its group and the **third** lowest first ionisation energy in its period?

- A boron
- B calcium
- C magnesium**
- D sodium



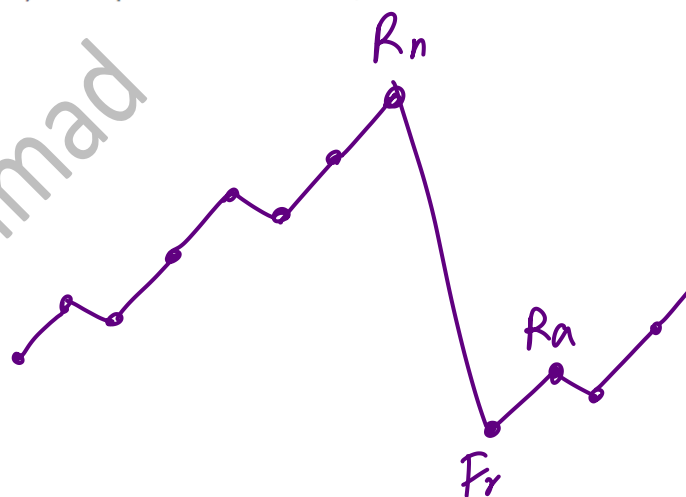
w/14/qp11

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

The elements radon (Rn), francium (Fr) and radium (Ra) have proton numbers 86, 87 and 88 respectively.

What is the order of their first ionisation energies?

	least endothermic	→	most endothermic
A	Fr		Ra Rn
B	Fr		Rn Ra
C	Ra		Fr Rn
D	Rn		Ra Fr



s/13/qp11

3 The first six ionisation energies of four elements are given.

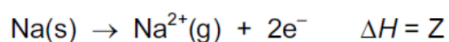
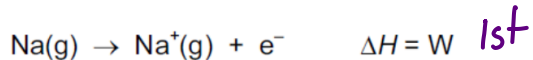
Which element is most likely to be in Group IV of the Periodic Table?

	ionisation energy / kJ mol ⁻¹					
	1st	2nd	3rd	4th	5th	6th
A	494	4 560	6 940	9 540	13 400	16 600
B	736	1 450	7 740	10 500	13 600	18 000
C	1 090	2 350	4 610	6 220	37 800	47 000
D	1 400	2 860	4 590	7 480	9 400	53 200

gp 4

s/13/qp13

2 Equations involving four enthalpy changes are shown.



What is the second ionisation energy of sodium?

A X

B X - W

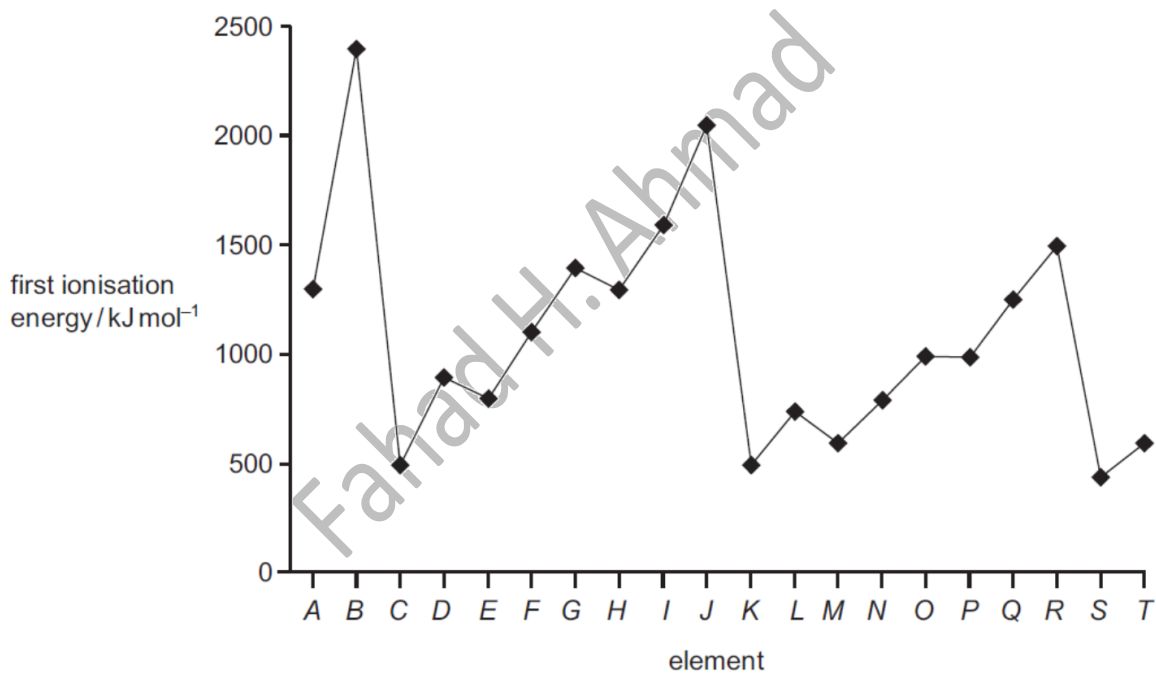
C Y - W

D Z - Y

s/13/qp12

34 The first ionisation energies of twenty successive elements in the Periodic Table are represented in the graph.

The letters given are not the normal symbols for these elements.



Which statements about this graph are correct?

1 Elements B, J and R are in Group 0 of the Periodic Table. ✓

2 Atoms of elements D and L contain two electrons in their outer shells. ✓

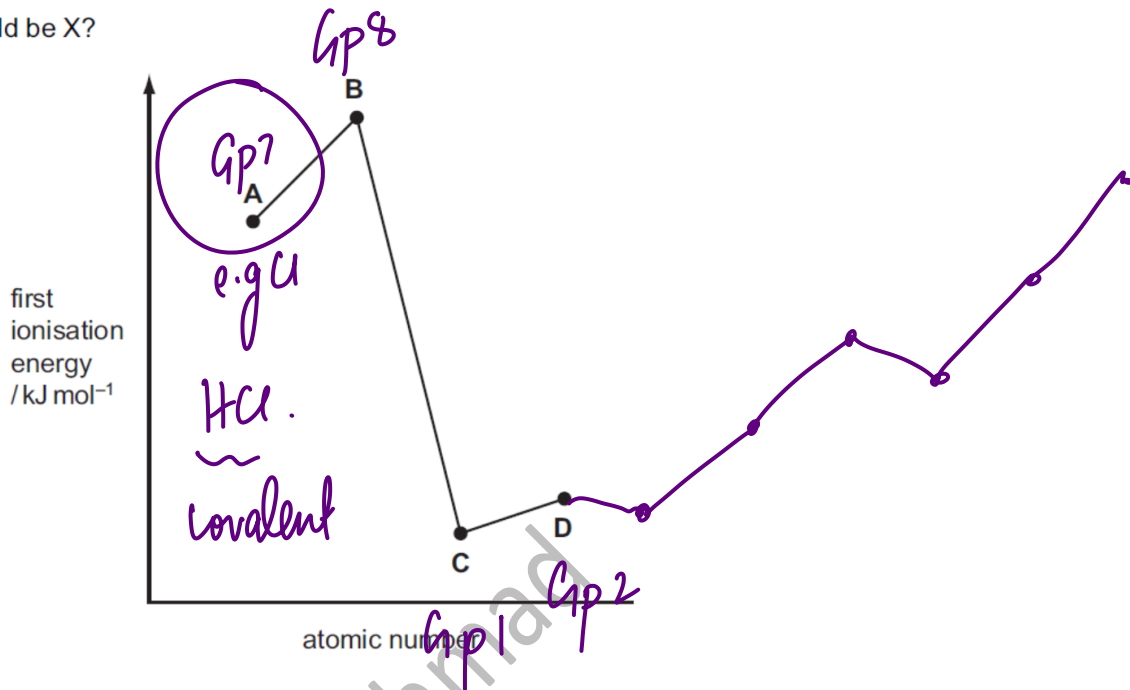
3 Atoms of elements G and O contain a half-filled p subshell. ✓

s/13/qp11

10 Shown on the graph are the relative values of the first ionisation energies of four elements that have consecutive atomic numbers.

One of the elements reacts with hydrogen to form a covalent compound with formula HX.

Which element could be X?



s/14/qp12

Types of Chemical Bonding

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 ✓

low MP/BP
poor electrical conductors
solubility varies

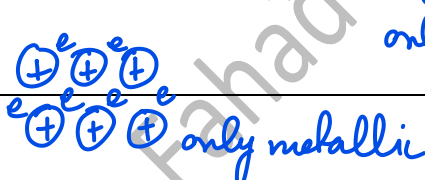
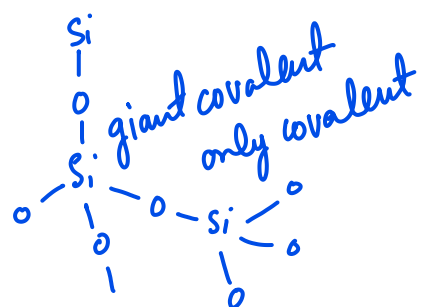
s/18/qp12

6 Which solid contains more than one type of bonding?

- A** iodine
- B silicon dioxide
- C sodium chloride
- D zinc

I-I Vanderwaals
I-I covalent

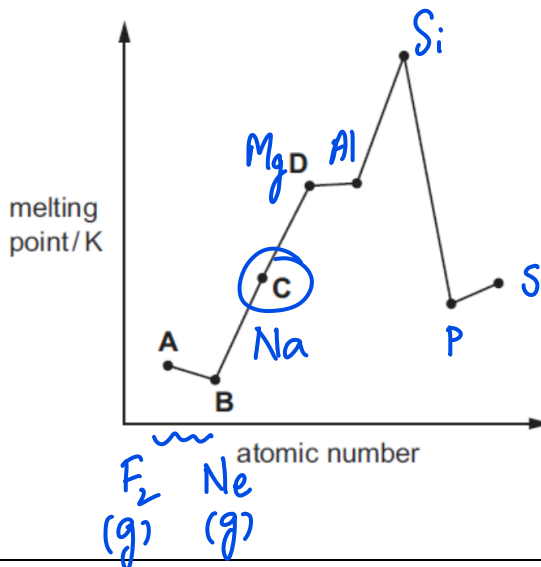
Na⁺ Cl⁻ Na⁺
Cl⁻ Na⁺ Cl⁻
only ionic



s/18/qp11

13 The diagram shows the melting points of eight elements with consecutive atomic numbers.

Which element could be sodium?



w/16/qp11

1 Which type of bonding is **never** found in elements?

A covalent

B ionic

C metallic

D van der Waals' forces

→ for ionic, metal + nonmetal
different elements

w/15/qp12

15 The melting points of the Period 3 elements sodium to aluminium are shown in the table.

element	Na	Mg	Al
mp/K	371	923	932

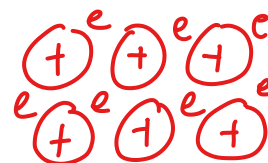
Which factor explains the **increase** in melting points from sodium to aluminium?

A the changes in first ionisation energy from sodium to aluminium

B the increase in electronegativity from sodium to aluminium

C the increase in the A_r of the elements from sodium to aluminium

D the increase in the number of outer electrons in each atom from sodium to aluminium



metallic bonding.

more delocalized e^-
stronger attraction

w/15/qp11

32 Which allotropes of carbon have a giant molecular structure?

1 buckminsterfullerene

2 diamond

3 graphite

→ bulky balls have a specific size e.g. C_{60}

diamond and graphite have unlimited/giant structures

s/17/qp12

32 Graphene, graphite and the fullerene C_{60} are allotropes of carbon.

Which statements are correct for all three of these allotropes of carbon?

1 Delocalised electrons are present in the structure.

2 All bond angles are 120° .

3 It has a giant molecular crystalline lattice structure.

C_{60} is not giant

S/17/qp11

32 Three elements, X, Y and Z, have electronic configurations as shown.

X	Y	Z
2,6	2,8,1	2,8,7

Which formulae represent compounds that conduct electricity in the liquid state?

- 1 YZ ✓
 2 Y₂X ✓
 3 Z₂X ✗

gp 6 gp 1 gp 2
 metal
 ionic

s/16/qp12

36 In which different forms does nitrogen exist in compounds?

- 1 bonded by a triple covalent bond ✓ $H-C \equiv N$
 2 as part of a cation ✓ NH_4^+
 3 in an oxidation state of +5 ✓ NO_3^-

m/18/qp12

12 The electrical conductivities of two compounds, Y and Z, are shown in the table.

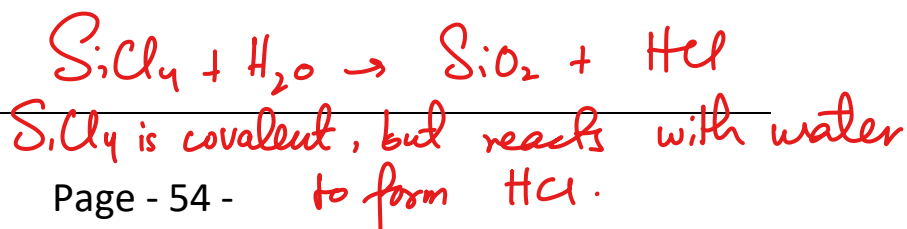
	Y	Z
conductivity of the compound in the liquid state	good	does not conduct
conductivity of the mixture obtained by adding the compound to water	good	good

What could compounds Y and Z be?

	Y	Z
A	Al ₂ O ₃	SiCl ₄
B	NaF ✓	Al ₂ O ₃
C	NaF ✓	SiCl ₄ ✓
D	SiCl ₄	Al ₂ O ₃

ionic
 dissolves in water

Al₂O₃
 does not dissolve



m/17/qp12

- 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

read basic description of graphene

m/16/qp12

- 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. *X SiO_2 is giant*
 C Both solids have atoms joined by single covalent bonds. *X CO_2 has double bonds*
 D Both solids change spontaneously to gas at s.t.p.

solids have lattice structure

SiO_2 has very high melting points

m/16/qp12

- 5 Which of the following solids has a simple molecular lattice?

- A magnesium oxide
 B sodium
 C silicon(IV) oxide
 D sulphur S_8

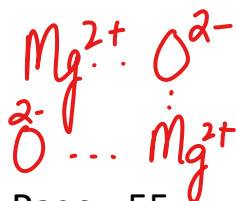
covalent molecule

s/03/qp1

- 6 Magnesium oxide is used to line industrial furnaces because it has a very high melting point.

Which type of bond needs to be broken for magnesium oxide to melt?

- A co-ordinate
 B covalent
 C ionic
 D metallic



s/04/qp1

34 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

s/04/qp1

6 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

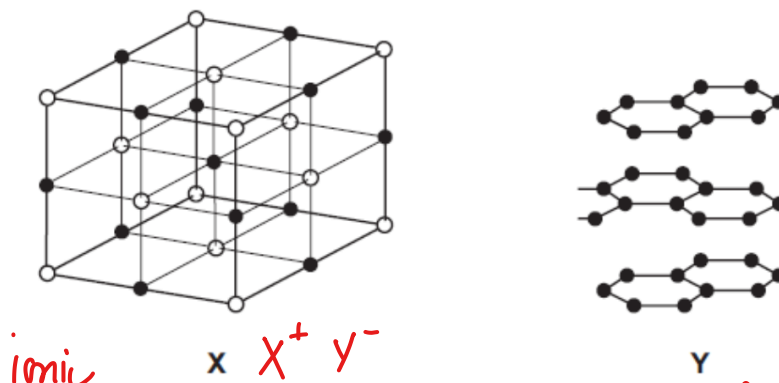
} ionic
graphite

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

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

s/05/qp1

- 7 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

s/06/qp1

- 12 Which chlorine compound has bonding that can be described as ionic with some covalent character?

A NaCl

B MgCl₂

C AlCl₃

D SiCl₄

s/07/qp1

ionic

ionic

covalent

covalent

electronegativity difference > 1.7

- 7 Which pair of elements have bonds of the same type between their atoms in the solid state?

A aluminium and phosphorus

B chlorine and argon

C magnesium and silicon

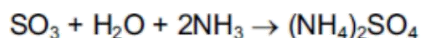
D sulphur and chlorine

both covalent S₈ Cl₂

s/08/qp1

17 Deposits of ammonium compounds have been discovered in areas of high atmospheric pollution.

They are believed to arise from the following reaction.



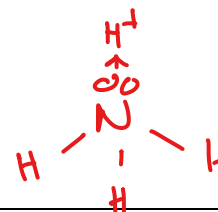
What does **not** occur in this reaction?

- A acid / base neutralisation ✓ $\text{NH}_3 \rightarrow \text{NH}_4^+$ gains H^+
- B dative bond formation ✓
- C ionic bond formation ✓ $\text{NH}_4^+ \text{SO}_4^{2-}$

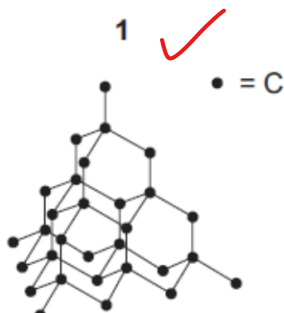
D oxidation/reduction

s/09/qp1

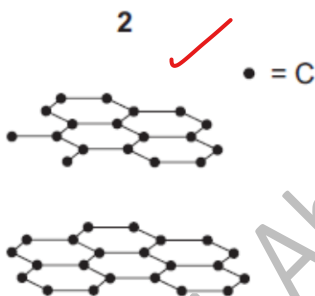
no redox



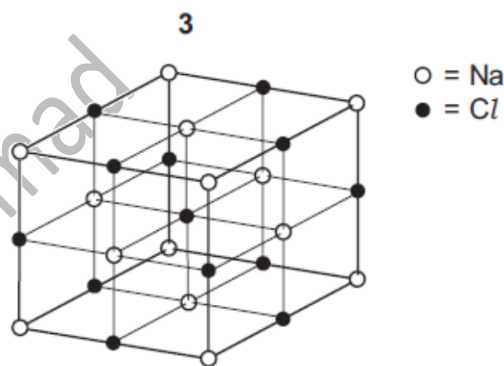
31 Which diagrams represent part of a giant molecular structure?



diamond



graphite



ionic

s/10/qp11

10 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

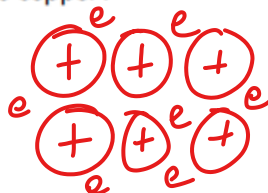
What could be the identities of R, S and T?

	R	S	T
A	MgO	NaCl	C [graphite]
B	MgO	NaCl	SiO ₂
C	NaCl	MgO	C [graphite]
D	NaCl	MgO	SiO ₂

s/11/qp11

32 Which are features of the structure of metallic copper?

- 1 a lattice of ions ✓
- 2 delocalised electrons ✓
- 3 ionic bonds ✗

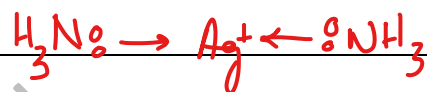
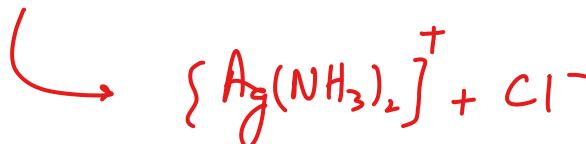
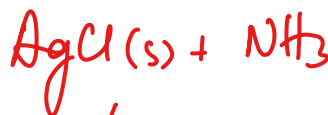


s/11/qp11

34 Silver chloride dissolves in aqueous ammonia.

What happens in this process?

- 1 A co-ordinate bond is formed. ✓
- 2 The oxidation number of nitrogen is unchanged. ✓
- ✗ Ammonia acts as a Brønsted-Lowry base.



s/11/qp12

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

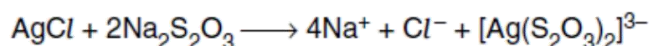
- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

- A brass
- B paper
- C poly(ethene)**
- D silicon(IV) oxide

w/03/qp1

16 In black and white photographic film, light converts silver chloride into metallic silver. After the film has been developed, the unexposed silver chloride is removed by reaction with sodium thiosulphate to produce a 'fixed' negative.



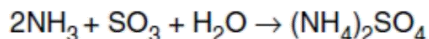
What is the function of thiosulphate?

- A to make the silver ions soluble**
- B to oxidise the silver ions
- C to oxidise the silver metal
- D to reduce silver ions

formation of complex ion
makes substance
more soluble

w/03/qp1

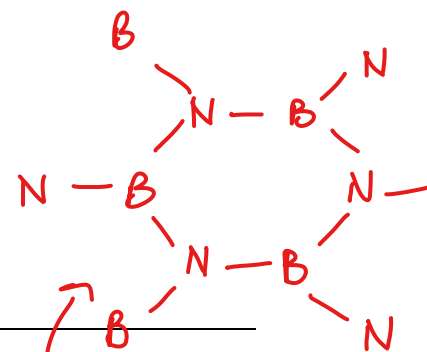
- 31 It is suggested that the solid deposits of ammonium compounds on the leaves of trees found in areas of high pollution are caused by the following reaction.



Which of these take place in this reaction?

- 1 an acid-base reaction ✓
- 2 ionic bond formation ✓
- 3 oxidation and reduction ✗

w/03/qp1



- 33 Boron is a non-metallic element which is placed above aluminium in Group III of the Periodic Table. It forms a compound with nitrogen known as boron nitride which has a graphite structure.

Which of the following conclusions can be drawn from this information?

- ✓ 1 The empirical formula of boron nitride is BN. $\text{B}^{3+} \text{N}^{3-}$
- 2 The boron and nitride atoms are likely to be arranged alternately in a hexagonal pattern. ✓
- 3 Boron nitride has a layer structure with van der Waals' forces between the layers. ✓

w/05/qp1

- 7 Magnesium oxide may be used for the lining of an electric furnace for making crockery.

Which properties of magnesium oxide help to explain this use?

	strong forces between particles	ionic bonding	electrical conductor
A	yes ✓	yes ✓	no ✓
B	yes ✓	no	yes
C	no	yes	no
D	no	no	yes

only conducts when molten

w/06/qp1

- 7 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

w/07/qp1

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

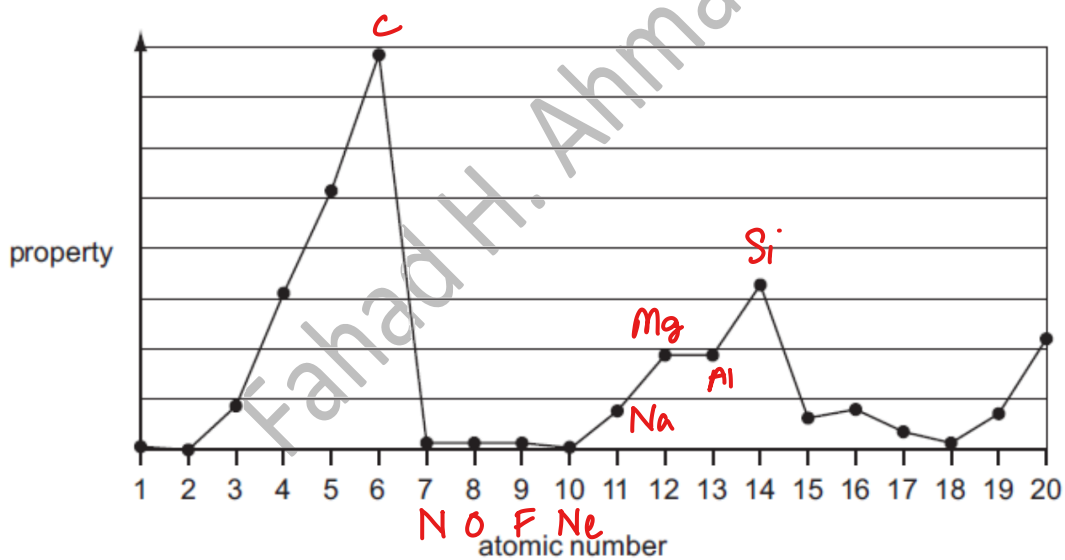
- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

- A brass
- B paper
- C** poly(ethene)
- D silicon(IV) oxide

w/08/qp1

12 The following graph shows the variation of a property of the first 20 elements in the Periodic Table with the atomic number of the element.



What is the property?

- A atomic radius
- B first ionisation energy
- C ionic radius
- D** melting point

w/09/qp11

5 Which solid has a simple molecular lattice?

- A calcium fluoride
- B nickel
- C silicon(IV) oxide
- D** sulfur S_8

w/10/qp12

1 Three elements, X, Y and Z, have the physical properties shown in the table.

element	melting point /°C	boiling point /°C	density /g cm ⁻³
X	-7	59	3.12
Y	98	883	0.97
Z	649	1107	1.74

$Br_2(l)$

→ Cu metals
have low density
and low MP

What could be the identities of X, Y and Z?

	X	Y	Z
A	Br_2	Al	Si
B	Br_2	Na	Mg
C	I_2	Mg	Na
D	I_2	Si	K

w/11/qp11

6 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	KCl	NH ₃
B	MgO	NaF	C ₂ H ₅ Br
C	SiO ₂	KCl	C ₂ H ₅ Br
D	SiO ₂	NaF	HCl

MgO

NaF

C₂H₅Br

ionic

both NH₃ and HCl
are gases at r.t.p

strong
insoluble

w/11/qp12

8 Some car paints contain small flakes of silica, SiO₂.

In the structure of solid SiO₂

- 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

w/12/qp11

33 Which of these substances have a giant structure?

- 1 silicon(IV) oxide ✓
- 2 baked clay found in crockery SiO_2 ✓
- 3 phosphorus(V) oxide ✗

w/12/qp11

↳ simple molecule

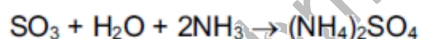
31 How may nitrogen exist in compounds?

- 1 bonded by a triple covalent bond ✓ $\text{H}-\text{C}\equiv\text{N}$
- 2 as part of a cation NH_4^+
- 3 having lost 3 electrons to form an anion ✗

w/12/qp11

19 Deposits of ammonium sulfate have been discovered in areas of high atmospheric pollution.

They are believed to arise from the following reaction.

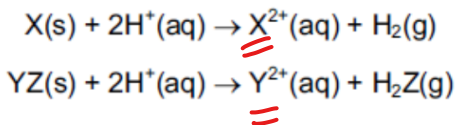


What does **not** occur in this reaction?

- A acid / base neutralisation
- B dative bond formation
- C ionic bond formation
- D oxidation / reduction ✗

w/12/qp13

34 An element X and compound YZ react separately with acid as shown.



When 1.0 g of either X or YZ is reacted with an excess of acid, the total volume of gas formed is the same.

Which statements are correct?

- 1 $A_r(\text{X}) = M_r(\text{YZ})$ ✓
- 2 X and Y are metals. ✓ form +ve ions
- 3 X and Y must both be in the same Group of the Periodic Table. ✗

w/12/qp13

same mass, same volume, same ratio
so molar mass should be same

both +2 ions
could be Al^{2+} or
transition metals

33 Which substances have a giant structure?

- 1 calcium oxide ✓ giant ionic
- 2 calcium ✓ giant metallic
- 3 baked clay found in crockery ✓ SiO_2 giant covalent

w/12/qp13

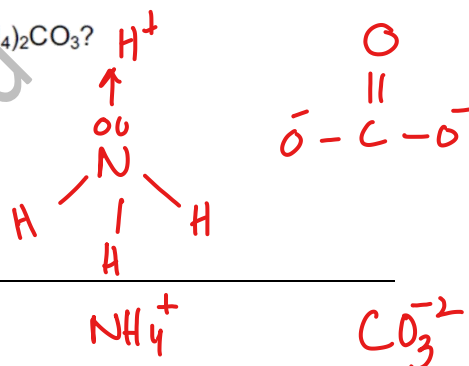
31 How may nitrogen exist in compounds?

- ✓ 1 bonded by a triple covalent bond $\text{H}-\text{C}\equiv\text{N}$
- ✓ 2 as part of a cation NH_4^+
- ✓ 3 in an oxidation state of +5 NO_3^-

w/12/qp13

35 Which types of bonding are present in ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$?

- 1 ionic ✓
- 2 covalent ✓
- 3 co-ordinate (dative covalent) ✓



w/13/qp11

5 The table shows the physical properties of four substances.

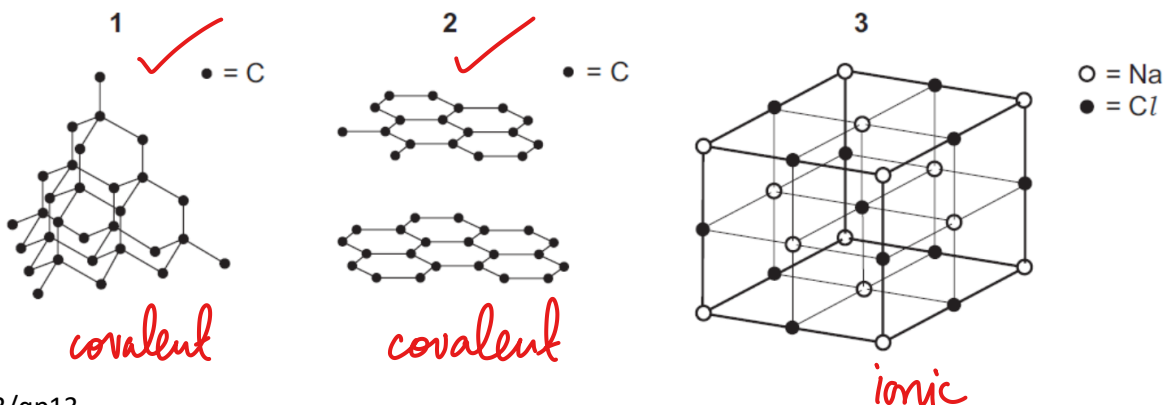
Which substance could be hydrogen chloride?

→ HCl is a gas at r.t.p

	melting point /°C	electrical conductivity of solid	electrical conductivity of liquid	electrical conductivity of aqueous solution
A	-119	poor	poor	insoluble
B	-115	poor	poor	good ✓
C	-50	poor	poor	poor
D	993	poor	good	good

w/14/qp11

34 Which diagrams represent part of a giant molecular structure?

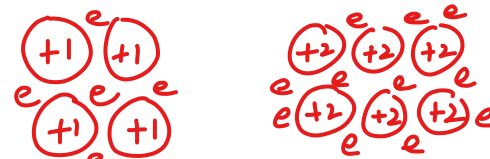


s/13/qp13

32 The Group II metals have higher melting points than the Group I metals.

Which factors could contribute towards the higher melting points?

- ✓ 1 There are smaller interatomic distances in the metallic lattices of the Group II metals. ✓
- ✓ 2 More electrons are available from each Group II metal atom for bonding the atom into the metallic lattice. ✓
- ✗ 3 Group II metals have a higher first ionisation energy than the corresponding Group I metal.



s/13/qp11

2 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

s/14/qp12

- 4 The table shows the physical properties of four substances.

Which substance has a giant covalent structure?

very high MP/BP

	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

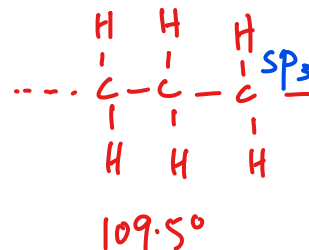
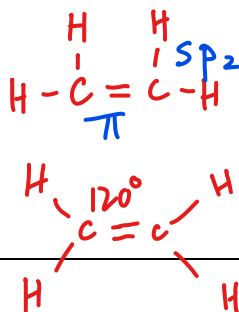
s/14/qp11

Fahad H. Ahmad

Sigma and Pi Bonds, Hybridization

1 Which feature is present in both ethene and poly(ethene)?

- ~~A~~ bond angles of 109°
- ~~B~~ π covalent bonds
- C** σ covalent bonds
- ~~D~~ sp^3 orbitals

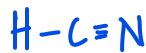


s/18/qp12

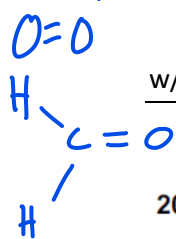
32 Which elements can form π bonds in their compounds?

- 1 carbon
- 2 oxygen
- 3 nitrogen

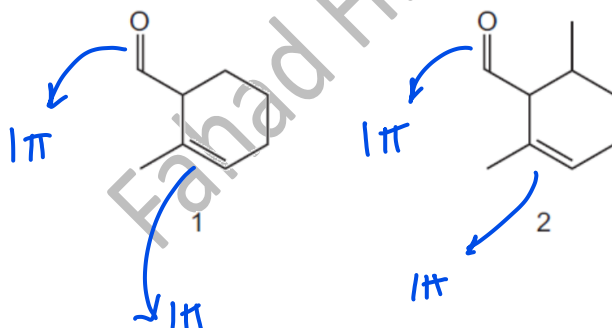
at least need a double bond (or a triple bond)



w/16/qp11



20 The diagrams show two different compounds.



What is

- the total number of structural isomers, including compound 2, that could be formed by adding a second methyl group to the ring of compound 1,
- the number of π electrons in each compound?

4e in each compound in π bonds

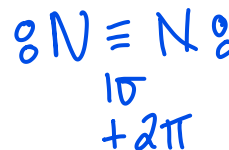
	number of isomers	number of π electrons
A	3	2
B	3	4
C	5	2
D	5	4

s/16/qp11

32 Nitrogen exists in air as covalently bonded diatomic molecules, N_2 .

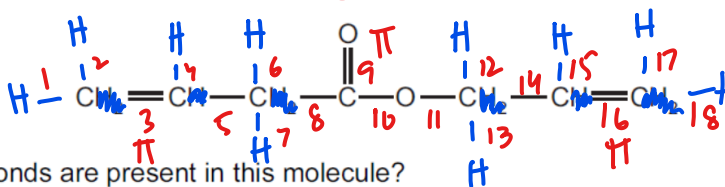
Which features are present in one N_2 molecule?

- 1 three π bonds
- 2 three shared pairs of electrons
- 3 two lone pairs of electrons



s/15/qp13

21 The diagram shows a molecule that has σ bonds and π bonds.



How many σ bonds are present in this molecule?

- A 15 B 17 C 18 D 21

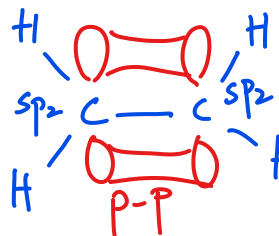


s/15/qp13

10 The double bond between the two carbon atoms in an ethene molecule consists of one σ bond and one π bond.

Which orbitals overlap to form each of these bonds?

	σ bond	π bond
A	sp^2-sp^2	p-p
B	sp^2-sp^2	sp^2-sp^2
C	sp^3-sp^3	p-p
D	sp^3-sp^3	sp^2-sp^2



s/15/qp11

4 Which molecule contains a nitrogen atom with sp hybridised orbitals?

- A $CH_3CH_2NH_2$ B HNO_3 C HCN D NH_3

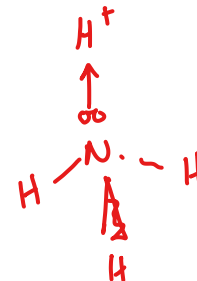
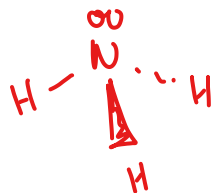
m/18/qp12



$\hookrightarrow 2\pi$ bonds

15 Which row of the table is correct?

	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal ✓	regular tetrahedral ✓	σ ✓	σ ✓
B	pyramidal ✓	regular tetrahedral ✓	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ



m/16/qp12

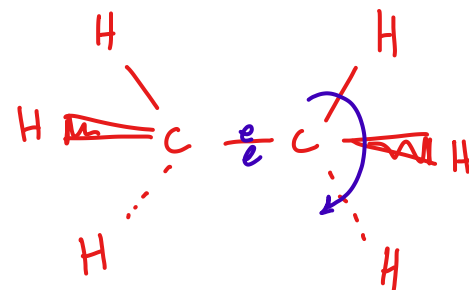
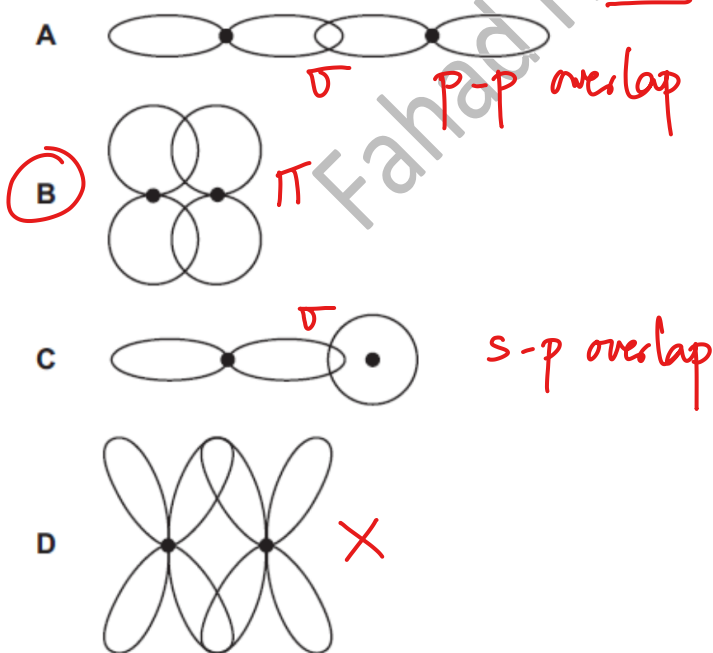
37 What is always involved in a carbon-carbon π bond?

- 1 a shared pair of electrons ✓
- 2 a sideways overlap of p orbitals ✓
- 3 delocalised electrons ✗



s/12/qp11

5 Which diagram describes the formation of a π bond from the overlap of its orbitals?



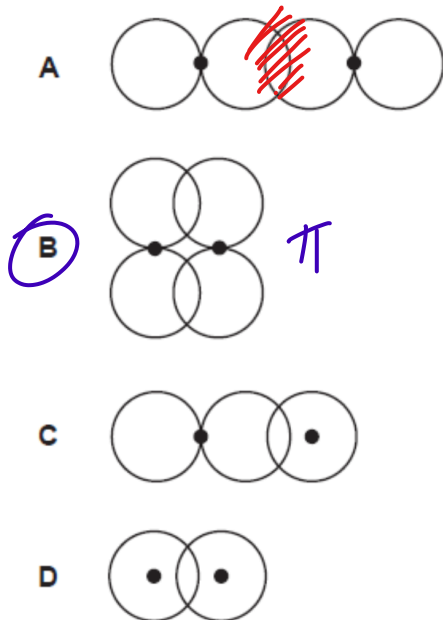
w/06/qp1

33 Which statements about covalent bonds are correct?

- 1 A triple bond consists of one π bond and two σ bonds. ~~X~~ \equiv ~~Y~~ ^{+2 π} _{σ}
- 2 The electron density in a σ bond is highest along the axis between the two bonded atoms. ✓
- 3 A π bond restricts rotation about the σ bond axis. ✓

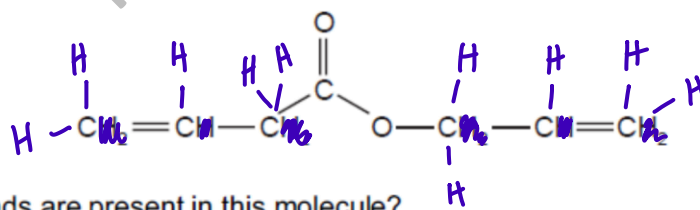
w/10/qp12

6 Which diagram represents the overlap of two orbitals which will form a π bond?



w/12/qp13

21 The diagram shows a molecule that has σ bonds and π bonds.

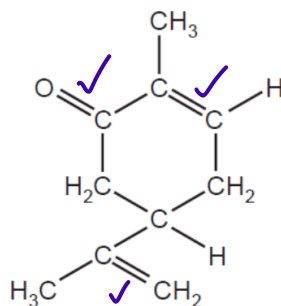


How many σ bonds are present in this molecule?

- A 15 B 17 C 18 D 21

w/12/qp13

20 Carvone is found in spearmint.



carvone

How many σ and π bonds are present in this molecule?

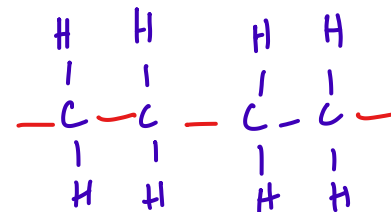
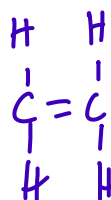
$$13\sigma + 3\pi$$

	σ	π
A	13	3
B	22	3
C	22	6
D	25	3

w/12/qp12

30 Which types of bond breakage and bond formation occur in the addition polymerisation of alkenes?

	bond breakage	bond formation
A	π only ✓	σ only ✓
B	π only ✓	σ and π
C	σ and π	σ only
D	σ and π	σ and π



w/13/qp11

33 Which elements have atoms which can form π bonds with atoms of other elements?

- 1 oxygen ✓
- 2 nitrogen ✓
- 3 fluorine

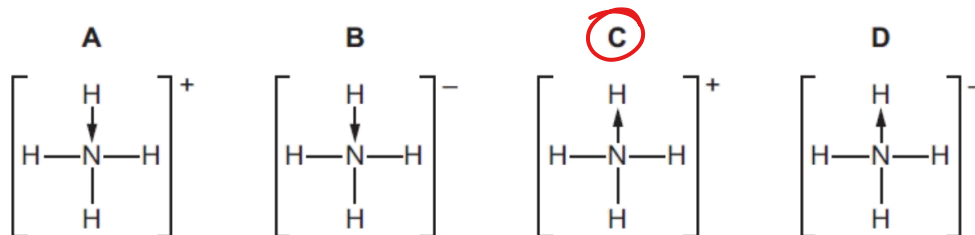
s/14/qp12

↳ cannot make double bonds

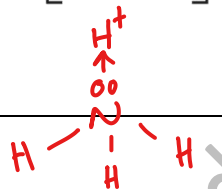
Bond Angles, Molecular Geometry, Lone Pairs, Dative Bonds

- 18 The dative covalent bond can be represented by an arrow, \rightarrow . The arrow points towards the atom receiving the lone pair.

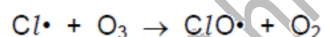
Which diagram of an ammonium ion is correct?



s/18/qp12



- 32 The chlorine oxide free radical, $\text{ClO}\cdot$, is produced by the reaction between chlorine atoms and ozone.



Which features are present in the chlorine oxide free radical?

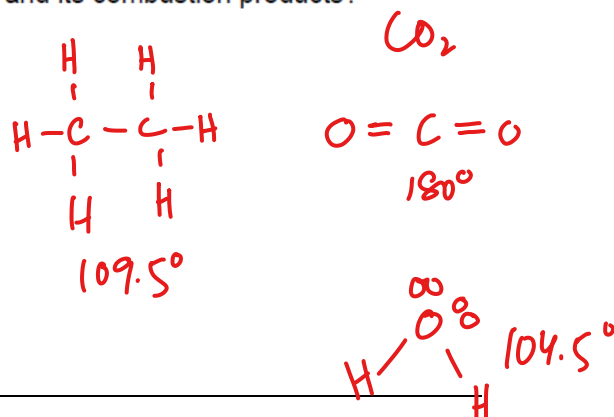
- 1 an odd number of electrons ✓ ClO $17e + 8e = 25e$
- 2 a single covalent bond ✓
- 3 a dative covalent bond from oxygen to chlorine ✗

w/17/qp12

- 4 Ethane burns in oxygen to produce carbon dioxide and water vapour.

Which bond angles are present in the molecules of ethane and its combustion products?

	ethane	combustion products
A	90°	104.5° and 180°
B	90°	109.5° and 120°
C	109.5° ✓	104.5° and 180°
D	109.5° ✓	109.5° and 180°



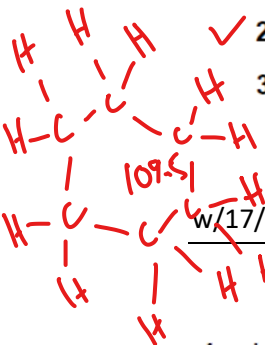
w/17/qp12

37 In which molecules do all the carbon atoms lie in the same plane?

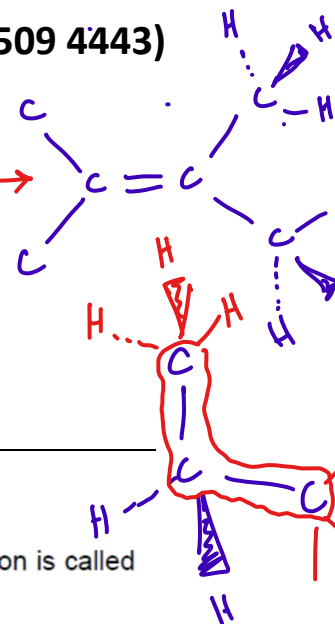
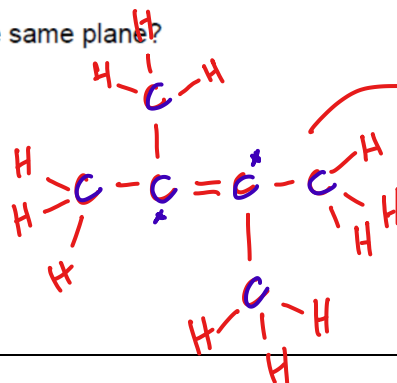
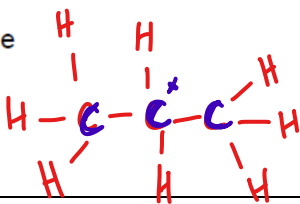
✓ 1 2,3-dimethylbut-2-ene

✓ 2 propane

3 X cyclohexane



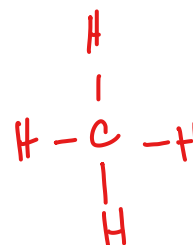
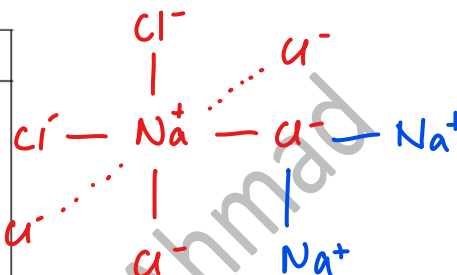
w/17/qp11



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



w/17/qp11

3 In which structure are three atoms bonded together in a straight line?

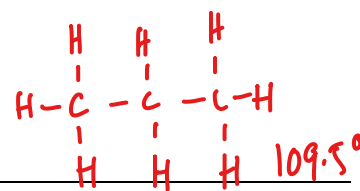
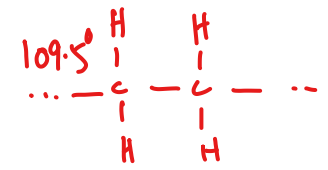
A poly(ethene), $(-CH_2CH_2)_n$ X

B propane, C_3H_8 X

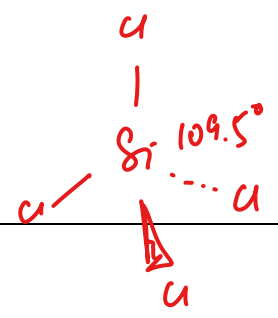
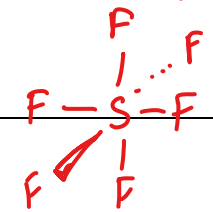
C silicon tetrachloride, $SiCl_4$

D sulfur hexafluoride, SF_6 ✓

180°



w/17/qp11



7 In which hydride is the H-X-H bond angle the smallest?

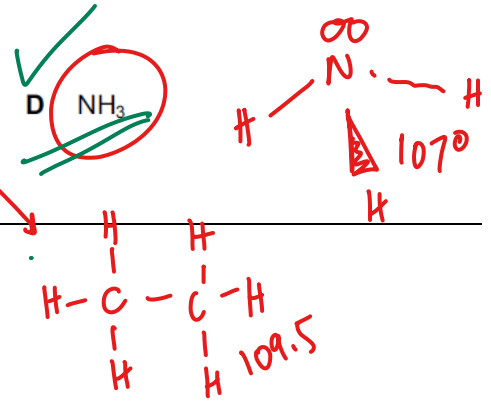
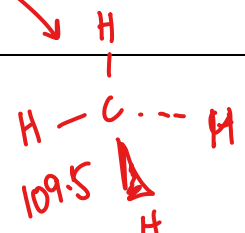
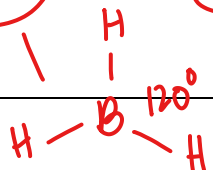
A **BH₃**

B **CH₄**

C C₂H₆

D NH₃

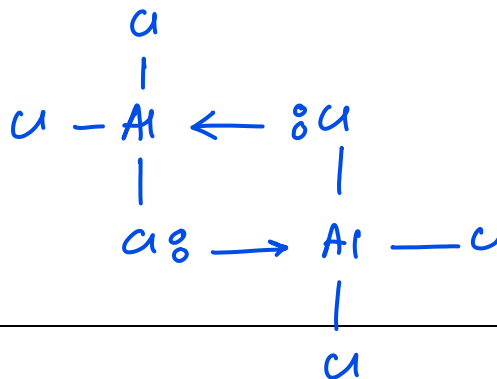
w/16/qp12



- 6 When solid aluminium chloride is heated, Al_2Cl_6 is formed.

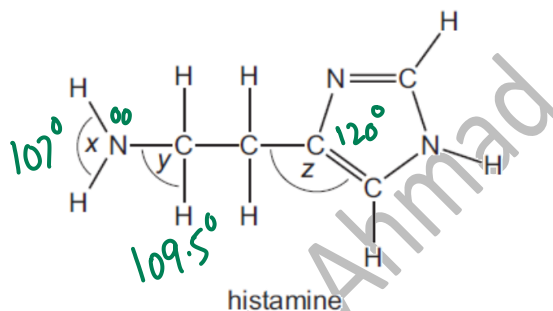
Which bonding is present in Al_2Cl_6 ?

- A** covalent and co-ordinate (dative covalent) ✓
B covalent only
C ionic and co-ordinate (dative covalent)
D ionic only



w/16/qp12

- 6 Histamine is produced in the body to help fight infection. Its shape allows it to fit into receptors which expand blood vessels.

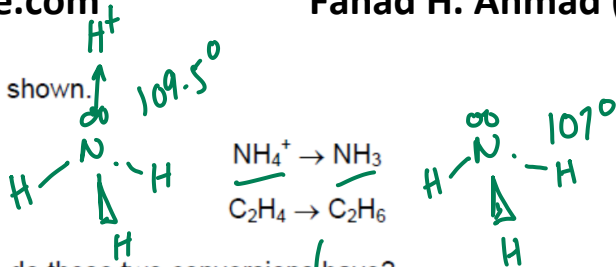


What are the bond angles x , y and z in histamine, from the smallest to the largest?

	smallest bond angle	→	largest bond angle
A	x		z
B	y		z
C	y		x
D	z		x

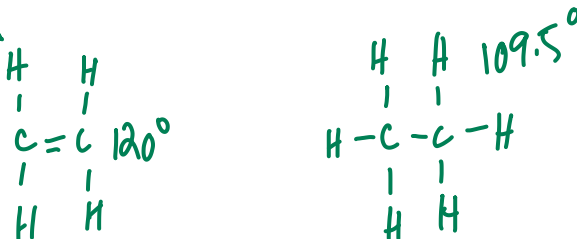
w/16/qp11

4 Two conversions are shown.



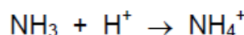
Which similar feature do these two conversions have?

- A change in oxidation state of an element
- B decrease in bond angle
- C formation of a lone pair of electrons
- D loss of a π bond



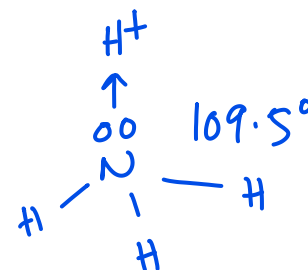
s/17/qp13

18 The ammonium ion is formed by the following reaction.



Which statement about the species involved in this reaction is correct?

- A The ammonia molecule contains a dative covalent bond.
- B The ammonium ion is a Brønsted-Lowry base as it has accepted a proton.
- C The H–N–H bond angle changes from 107° in ammonia to 90° in the ammonium ion.
- D The number of electrons surrounding each nitrogen atom does not change.



s/17/qp12

1 Which molecule contains six bonding electrons?

- A C_2H_4
- B H_2S
- C NCl_3
- D SF_6

s/17/qp11

36 Ammonia is a colourless gas that is produced by the Haber process.

Which statements about ammonia are correct?

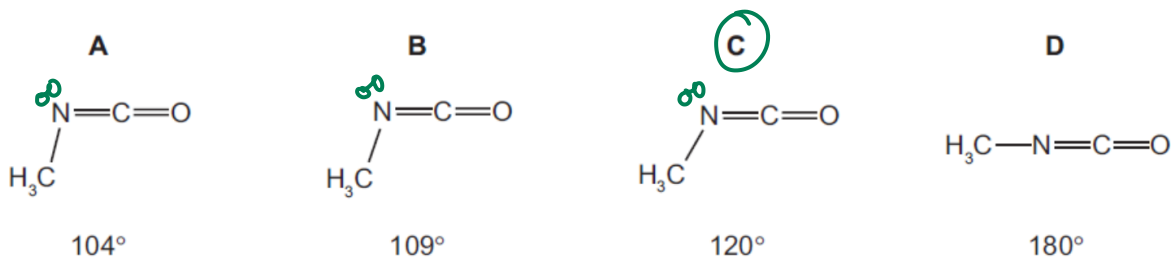
- ✓ 1 An ammonia molecule has three bond pairs and one lone pair of electrons.
- ✗ 2 If ammonia is bubbled into water the pH of the solution will increase. ammonia is basic
- 3 Ammonia gas can be made by warming ammonium sulfate with aqueous hydrochloric acid.



s/16/qp13

7 Methyl isocyanate, CH_3NCO , is a toxic liquid which is used in the manufacture of some pesticides.

What is the approximate angle between the bonds formed by the N atom in a molecule of methyl isocyanate?

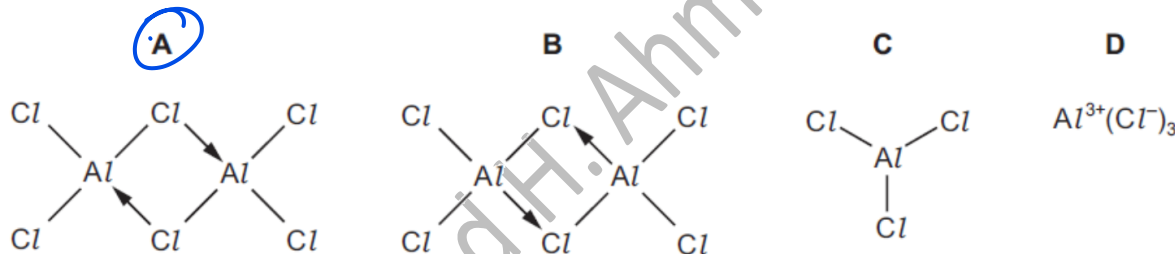


2 bond pairs + 1 lone pair

s/16/qp13

13 Solid aluminium chloride sublimes at 178°C .

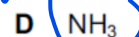
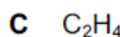
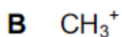
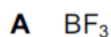
Which structure best represents the species in the vapour at this temperature?



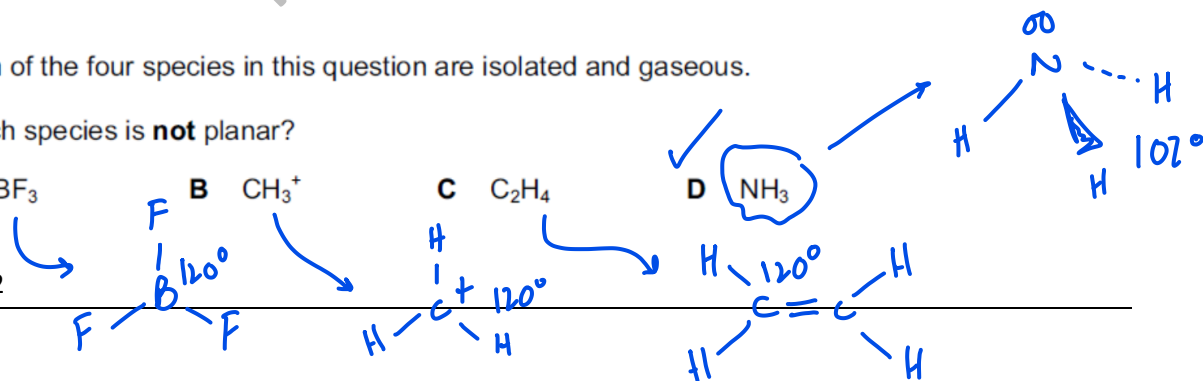
s/16/qp12

5 Each of the four species in this question are isolated and gaseous.

Which species is **not** planar?



s/16/qp12



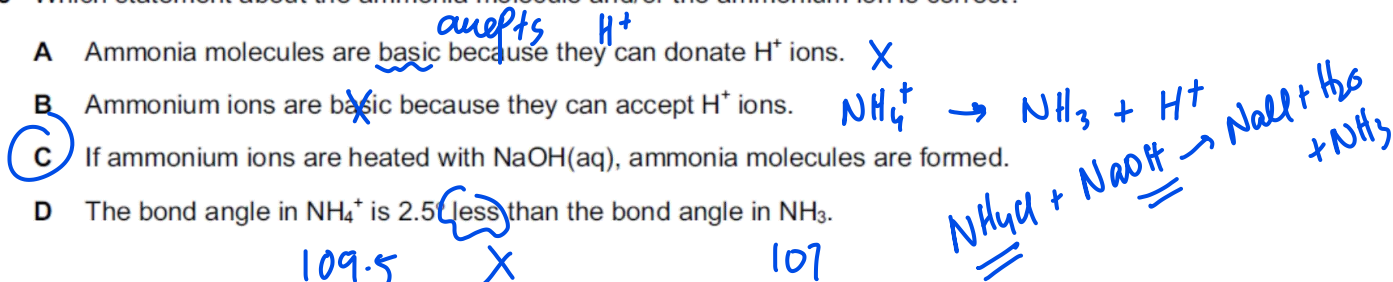
18 Which statement about the ammonia molecule and/or the ammonium ion is correct?

A Ammonia molecules are basic because they can donate H^+ ions. *accepts H^+* **X**

B Ammonium ions are basic because they can accept H^+ ions. **X**

C If ammonium ions are heated with NaOH(aq) , ammonia molecules are formed.

D The bond angle in NH_4^+ is 2.5° less than the bond angle in NH_3 .



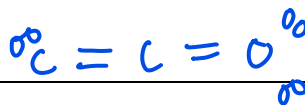
s/16/qp11

- 5 Dicarbon monoxide, C_2O , is found in dust clouds in space. The structure of this molecule is $C=C=O$. The molecule contains no unpaired electrons.

How many lone pairs of electrons are present in a molecule of C_2O ?

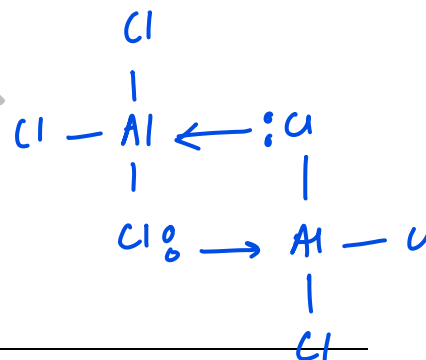
- A 1 B 2 C 3 D 4

s/16/qp11



- 2 What is the correct number of bonds of each type in the Al_2Cl_6 molecule?

	covalent	co-ordinate (dative covalent)
A	6	1
B	6	2
C	7	0
D	7	1

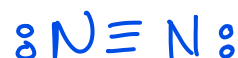


s/16/qp11

- 32 Nitrogen exists in air as covalently bonded diatomic molecules, N_2 .

Which features are present in one N_2 molecule?

- 1 three π bonds **X**
 2 three shared pairs of electrons **✓**
 3 two lone pairs of electrons **✓**

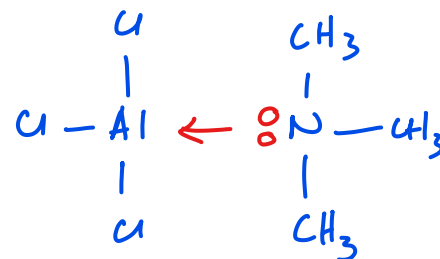


s/15/qp13

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

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

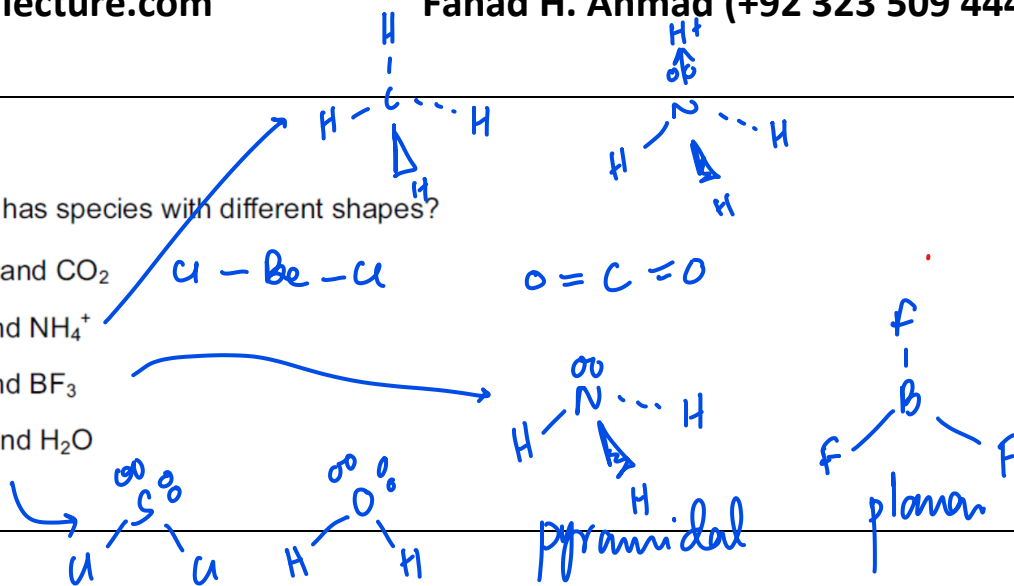
- A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.
 B The Al atom has an incomplete valence shell of electrons.
 C The bonds around the Al atom are planar. **tetrahedral**
D The molecules contain coordinate and covalent bonding



s/15/qp13

4 Which pair has species with different shapes?

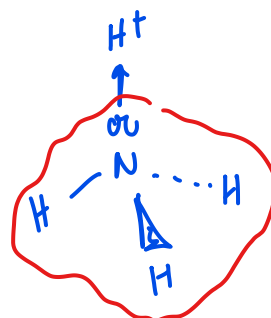
- A BeCl_2 and CO_2
- B CH_4 and NH_4^+
- C** NH_3 and BF_3
- D SCl_2 and H_2O



s/15/qp13

17 Which statement about the ammonium ion, NH_4^+ , is correct?

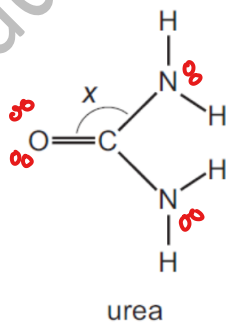
- A All bond angles are 107° . ~~109.5°~~
- B Ammonium ions are formed when ammonia behaves as an acid.
- C Ammonium ions are unreactive when heated with $\text{NaOH}(\text{aq})$.
- D** The bonds are all the same length.



s/15/qp12



32 Urea is a product of animal metabolism. It can also be used as a fertiliser.



4 lone pairs

The diagram shows angle x in this molecule.

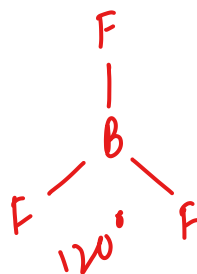
Which statements about the structure of urea are correct?

- 1 Angle x is approximately 120° . ✓
- 2 The molecule has two π bonds. ✗
- 3 The molecule has only three lone pairs of electrons. ✗

s/15/qp11

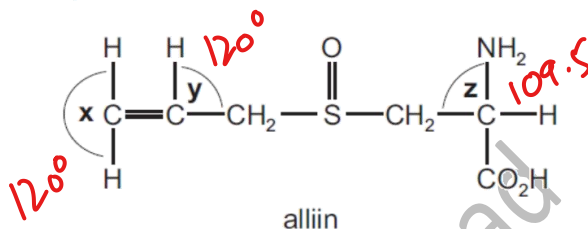
1 What are the shapes of the molecules of water and boron trifluoride?

	H ₂ O	BF ₃
A	linear	pyramidal
B	linear	trigonal
C	non-linear	pyramidal
D	non-linear	trigonal



m/18/qp12

5 The characteristic smell of garlic is due to alliin.



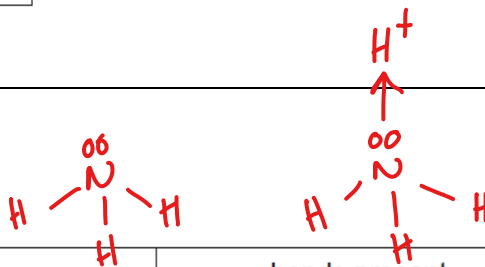
What are the approximate bond angles x , y and z in a molecule of alliin?

	x	y	z
A	90°	90°	109°
B	120°	109°	90°
C	120°	120°	109°
D	180°	109°	109°

m/17/qp12

15 Which row of the table is correct?

	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

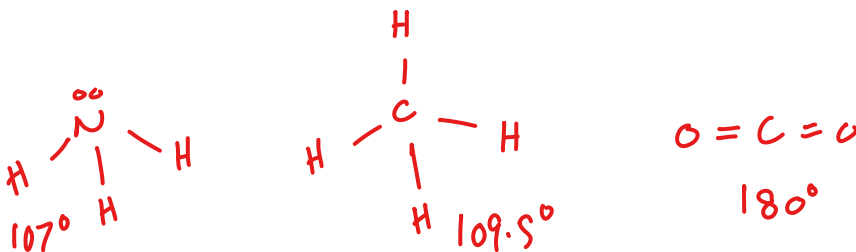


all single bonds \rightarrow sigma

m/16/qp12

6 Which series shows molecules in order of increasing bond angle?

- A $\text{CH}_4 \rightarrow \text{BF}_3 \rightarrow \text{NH}_3$
- B $\text{H}_2\text{O} \rightarrow \text{CO}_2 \rightarrow \text{BF}_3$
- C** $\text{NH}_3 \rightarrow \text{CH}_4 \rightarrow \text{CO}_2$
- D $\text{NH}_3 \rightarrow \text{CH}_4 \rightarrow \text{H}_2\text{O}$

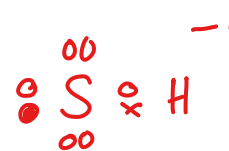


m/16/qp12

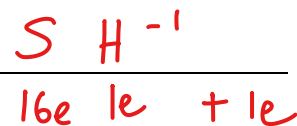
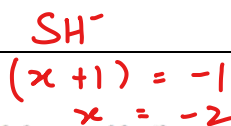
33 Sodium hydrosulfide, NaSH , is used to remove hair from animal hides.

Which statements about the SH^- ion are correct?

- 1 It contains 18 electrons. ✓
- 2 Three lone pairs of electrons surround the sulfur atom. ✓
- 3 Sulfur has an oxidation state of +2. ✗



s/10/qp11



5 The CN^- ion is widely used in the synthesis of organic compounds.

What is the pattern of electron pairs in this ion?

	bonding pairs of electrons	lone pairs on carbon atom	lone pairs on nitrogen atom
A	2	1	1
B	2	2	1
C	3 ✓	1 ✓	1 ✓
D	3 ✓	1 ✓	2

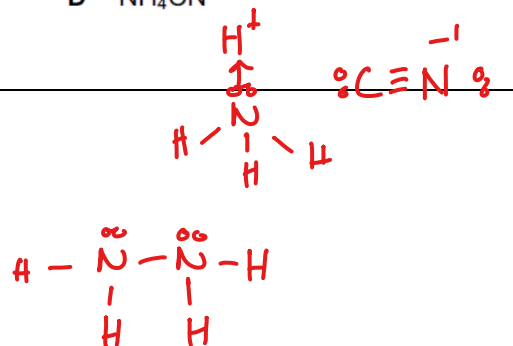
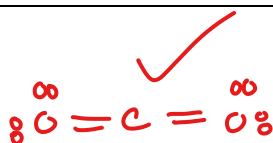
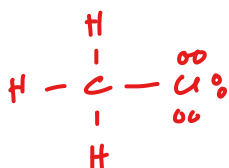


s/07/qp1

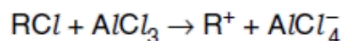
2 Which compound has the greatest total number of lone pairs of electrons in the valence shells of all of its atoms?

- A CH_3Cl
- B** CO_2
- C N_2H_4
- D NH_4CN

s/14/qp13

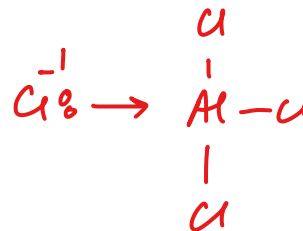


14 Aluminium chloride catalyses certain reactions by forming carbocations (carbonium ions) with chloroalkanes as shown.



Which property makes this reaction possible?

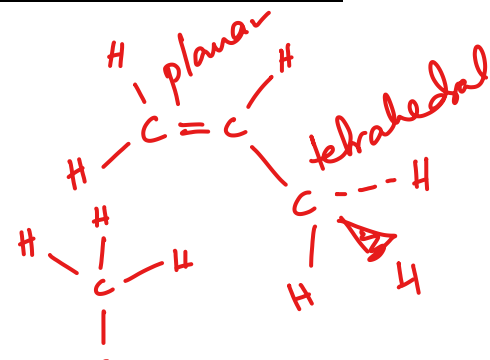
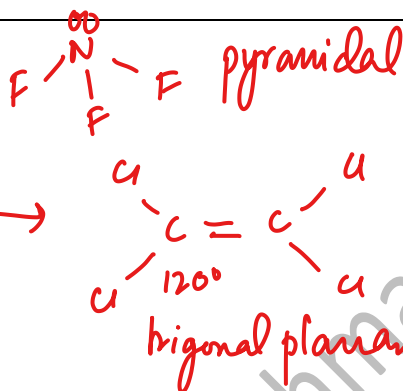
- A $AlCl_3$ is a covalent molecule.
- B $AlCl_3$ exists as the dimer Al_2Cl_6 in the vapour.
- C** The aluminium atom in $AlCl_3$ has an incomplete octet of electrons.
- D The chlorine atom in RCl has a vacant p orbital.



s/03/qp1

20 Which molecule is planar?

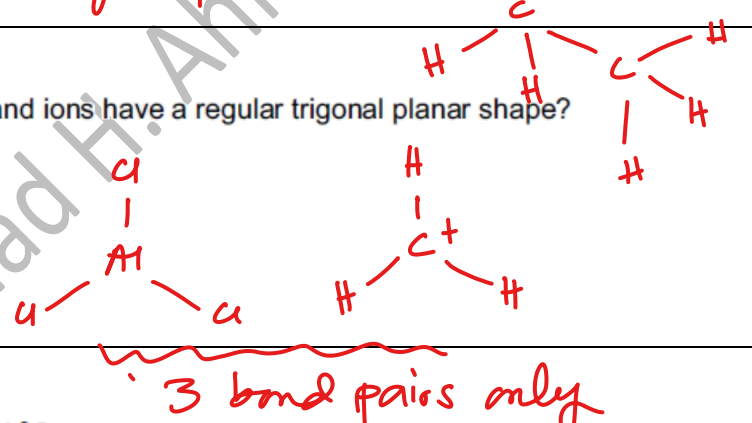
- A NF_3
- B** C_2Cl_4
- C C_3H_6
- D C_3H_8



s/04/qp1

31 Which of the following molecules and ions have a regular trigonal planar shape?

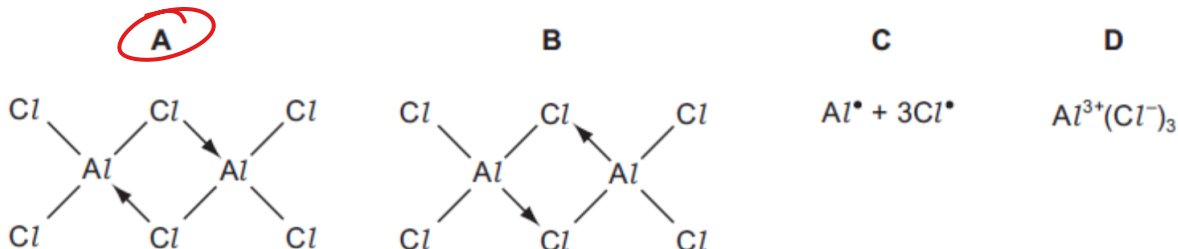
- 1 $AlCl_3$ ✓
- 2 CH_3^+ ✓
- 3 PH_3 ✗



s/05/qp1

15 Aluminium chloride sublimes at $178^\circ C$.

Which structure best represents the species in the vapour at this temperature?

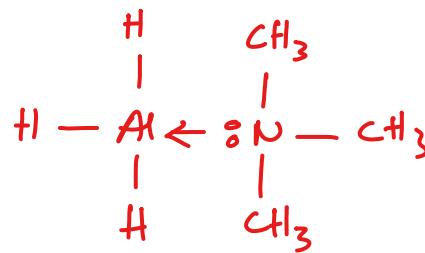


s/06/qp1

13 $AlCl_3$ reacts with $LiAlH_4$ and $(CH_3)_3N$ to give $(CH_3)_3NAlH_3$.

Which statement about $(CH_3)_3NAlH_3$ is correct?

- A It contains hydrogen bonding.
 B It is dimeric.
 C The Al atom has an incomplete octet of electrons.
 D The bonds around the Al atom are tetrahedrally arranged.

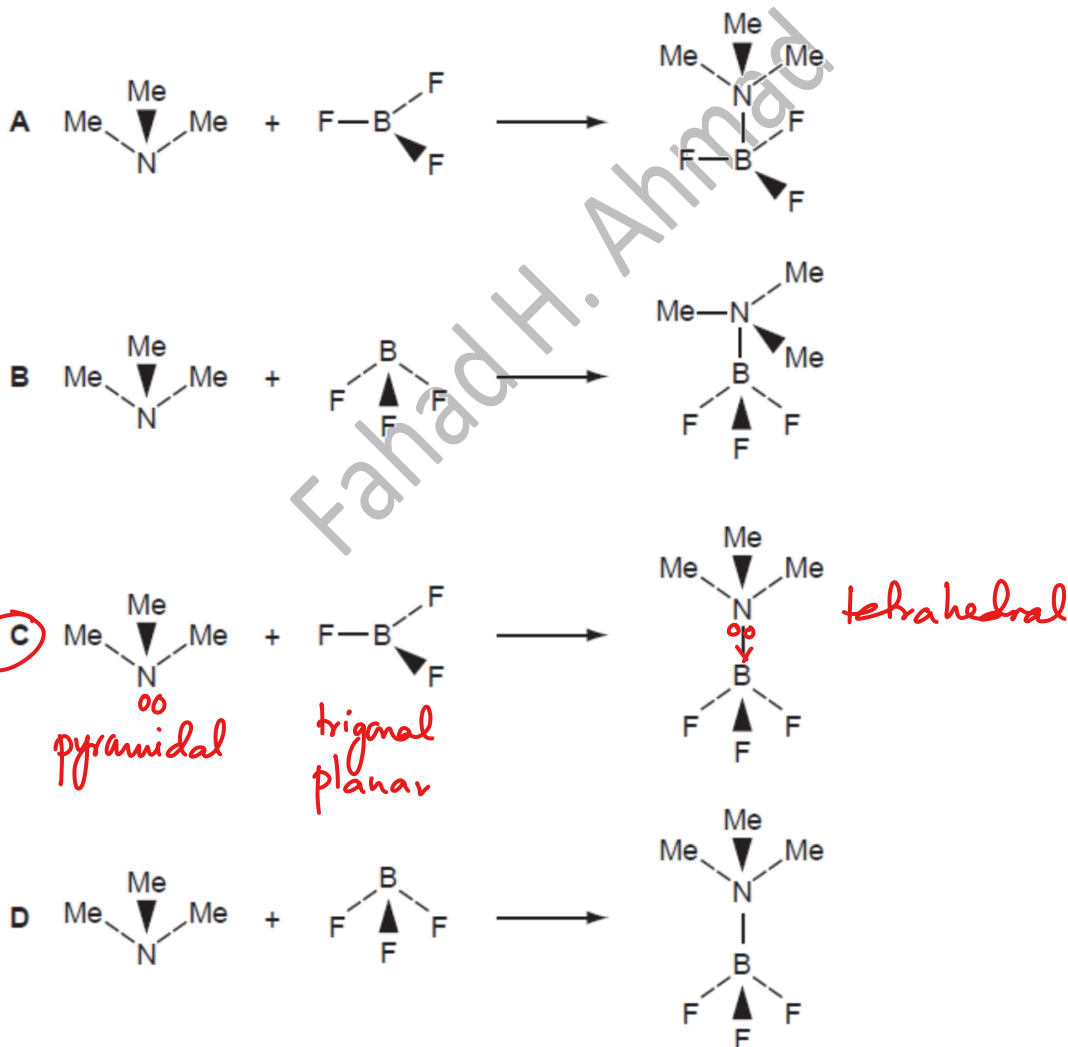


s/07/qp1

5 In this question, the methyl group, CH_3 , is represented by Me.

Trimethylamine, Me_3N , reacts with boron trifluoride, BF_3 , to form a compound of formula $Me_3N.BF_3$.

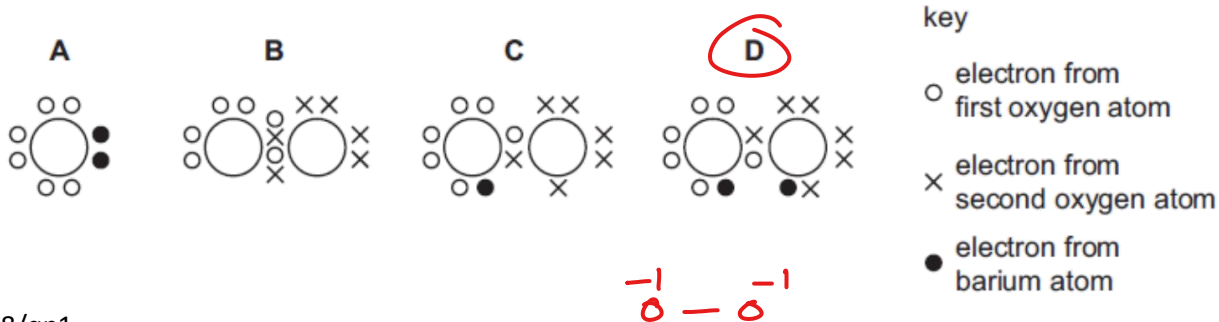
How may this reaction be written in terms of the shapes of the reactants and products?



s/08/qp1

- 4 When barium metal burns in oxygen, the ionic compound barium peroxide, BaO_2 , is formed.

Which dot-and-cross diagram represents the electronic structure of the peroxide anion in BaO_2 ?

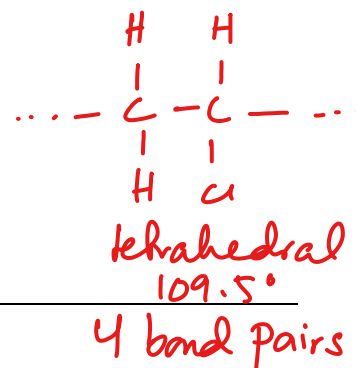
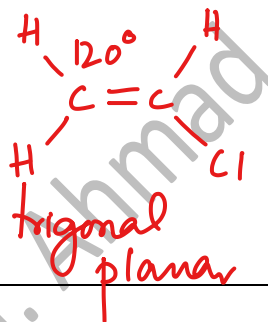


s/08/qp1

- 22 Chloroethene, $\text{CH}_2=\text{CHCl}$, is the monomer of PVC.

What are the C-C-C bond angles along the polymeric chain in PVC?

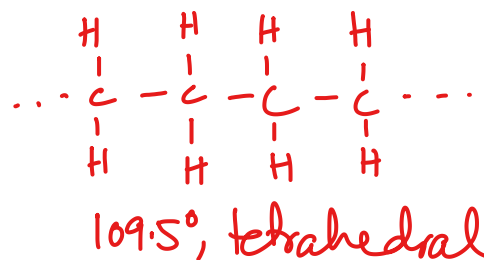
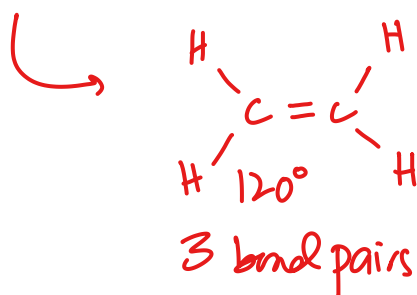
- A They are all 109.5° .
- B Half are 109.5° and half are 120° .
- C They are all 120° .
- D They are all 180° .



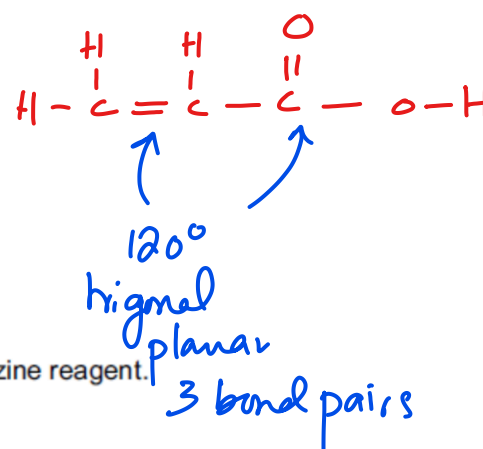
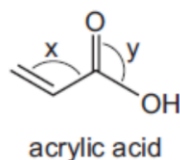
s/08/qp1

- 6 In which reaction does the carbon-containing product have a smaller bond angle than the organic reactant?
- A bromoethane refluxed with ethanolic sodium hydroxide
- B complete combustion of methane in air
- C methane and an excess of chlorine under ultraviolet light
- D polymerisation of ethene

s/09/qp1



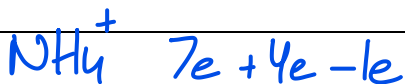
20 Acrylic acid is produced from propene, a gaseous product of oil refineries.



Which statement about acrylic acid is **not** correct?

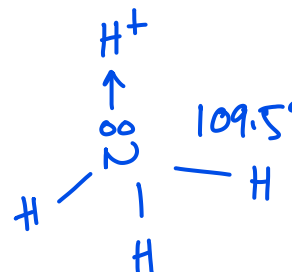
- A Both bond angles x and y are approximately 120°. ✓
- B It decolourises aqueous bromine. ✓
- C It gives an orange precipitate with 2,4-dinitrophenylhydrazine reagent.
- D It reacts with an alcohol to give an ester. ✓

s/11/qp11



37 Which descriptions of the ammonium ion are correct?

- 1 It contains ten electrons. ✓
- 2 It has a bond angle of 109.5°. ✓
- 3 It has only three bonding pairs of electrons.

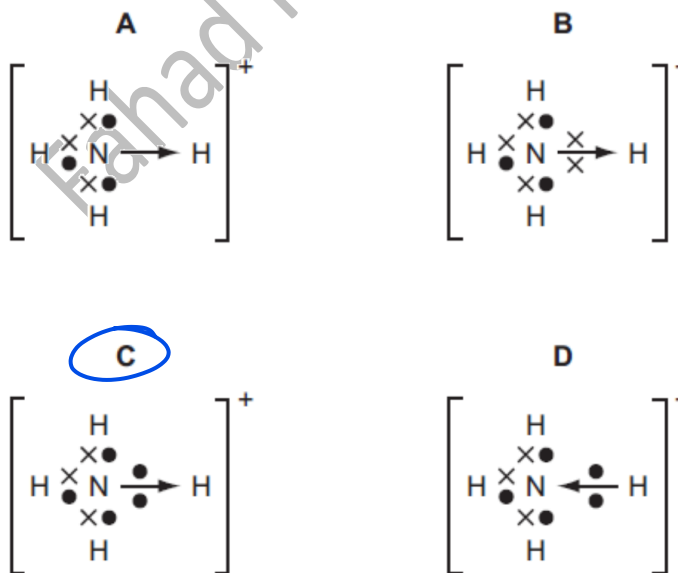


s/11/qp11

2 Which diagram correctly shows the bonding in the ammonium ion, NH_4^+ ?

key

- N electron
- × H electron



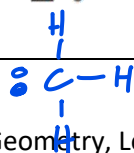
s/11/qp12



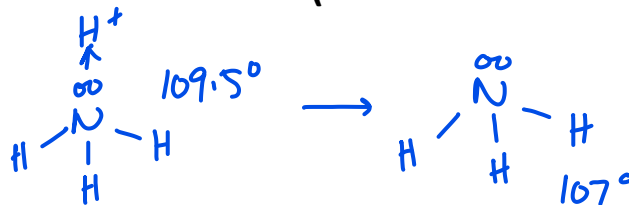
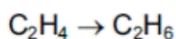
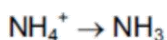
1 In which species does the underlined atom have an incomplete outer shell?

- A BF₃
- B CH₃⁻
- C F₂O
- D H3O⁺

s/12/qp11

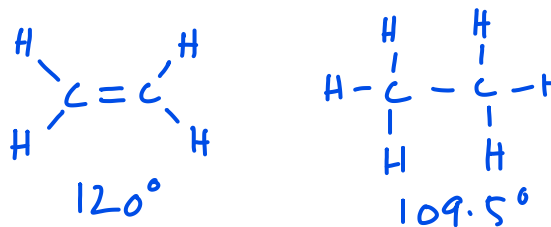


5 Two conversions are outlined below.



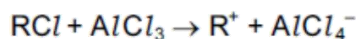
What similar feature do these two conversions have?

- A a lone pair of electrons in the product
- B change in oxidation state of an element
- C decrease in bond angle of the species involved**
- D disappearance of a π bond



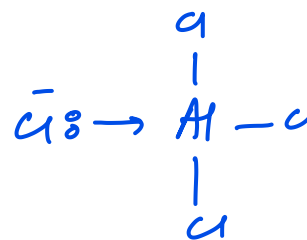
s/12/qp11

12 Aluminium chloride catalyses certain reactions by forming carbocations with chloroalkanes as shown.



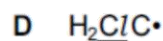
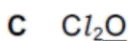
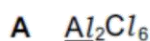
Which property makes this reaction possible?

- A AlCl_3 exists as the dimer Al_2Cl_6 in the vapour.
- B AlCl_3 is a covalent molecule.
- C The aluminium atom in AlCl_3 has an incomplete octet of electrons.**
- D The chlorine atom in RCl has a vacant p orbital.

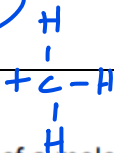


s/12/qp11

4 In which species does the underlined atom have an incomplete outer shell?

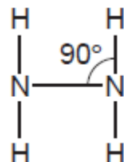


s/12/qp12

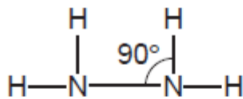


3 What is the most likely shape of a molecule of hydrazine, N_2H_4 ?

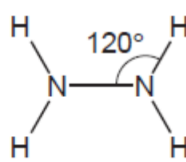
A



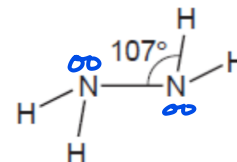
B



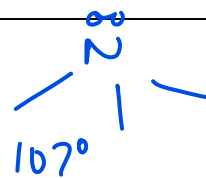
C



D

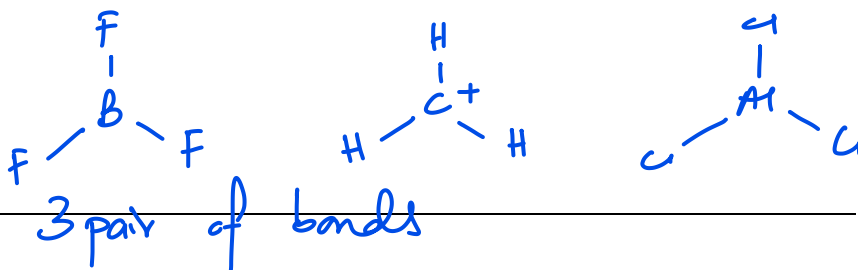


s/12/qp12



31 Which of the following molecules and ions have a regular trigonal planar shape?

- 1 BF_3 ✓
 2 CH_3^+ ✓
 3 AlCl_3 ✓

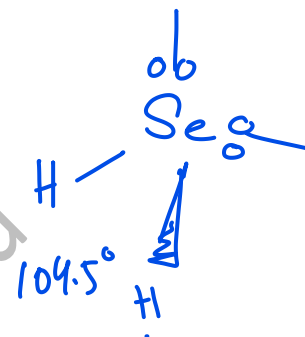


s/12/qp12

7 Chemists have been interested in the properties of hydrogen selenide, H_2Se , to compare it with 'bad egg' gas hydrogen sulphide, H_2S .

Which set of data would the hydrogen selenide molecule be expected to have?

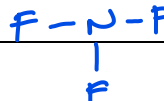
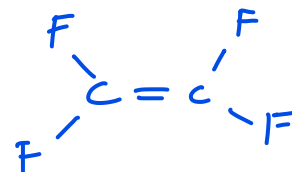
	number of lone pairs on Se atom	bond angle
A	1	104° ✓
B	2	104° ✓
C	2	109°
D	2	180°



w/03/qp1

6 Which molecule contains only six bonding electrons?

- A C_2H_4 B C_2F_6 C H_2O **D** NF_3



w/03/qp1

7 What are the bond angles in the PH_3 molecule likely to be?

- A 90° B 104° **C** 109° D 120°

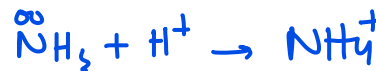
107°

old question / slightly incorrect

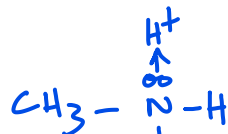
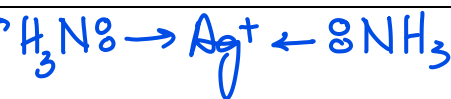
w/04/qp1

18 Which reaction of ammonia does **not** involve the non-bonding pair of electrons on the nitrogen atom?

- A $\text{NH}_3(\text{g}) + \text{CH}_3\text{I}(\text{g}) \rightarrow \text{CH}_3\text{NH}_3^+\text{I}^-(\text{s})$
 B $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$
C $2\text{NH}_3(\text{l}) + 2\text{Na}(\text{s}) \rightarrow 2\text{NaNH}_2(\text{s}) + \text{H}_2(\text{g})$
 D $2\text{NH}_3(\text{aq}) + \text{Ag}^+(\text{aq}) \rightarrow [\text{Ag}(\text{NH}_3)_2]^+(\text{aq})$



w/04/qp1



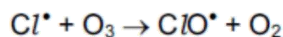
32 Which molecules are planar?

- 1 BCl_3 ✓
 2 NH_3 ✗
 3 PH_3 ✗



w/05/qp1

31 The chlorine oxide free radical, ClO^\bullet , is formed during the depletion of the ozone layer by chlorofluoroalkanes (CFCs).

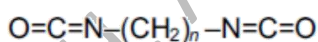


Which features are present in the chlorine oxide free radical?

- 1 an odd number of electrons ✓
 2 a single covalent bond ✓
 3 a dative covalent bond from oxygen to chlorine ✗

w/06/qp1

6 *Lycra*[®] is a polyurethane fibre used in the fashion industry. It is a polymer made from two monomers, one of which has the following formula.



2 bond pairs.

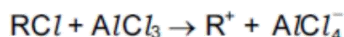
What is the O–C–N bond angle in this molecule?

180°

- A 90° B 109° C 120° **D 180°**

w/07/qp1

15 Aluminium chloride catalyses certain reactions by forming carbocations (carbonium ions) with chloroalkanes as shown.

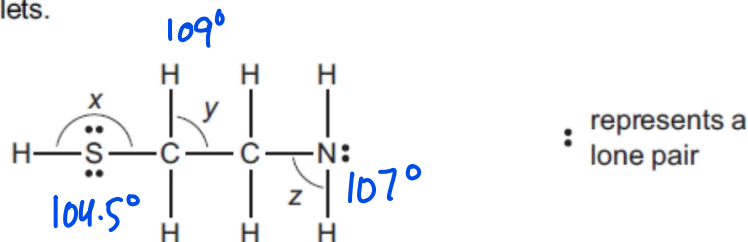


Which property makes this reaction possible?

- A AlCl_3 exists as the dimer Al_2Cl_6 in the vapour.
 B AlCl_3 is a covalent molecule.
C The aluminium atom in AlCl_3 has an incomplete octet of electrons.
 D The chlorine atom in RCl has a vacant p orbital.

w/08/qp1

- 4 The antidote molecule shown can help to prevent liver damage if someone takes too many paracetamol tablets.

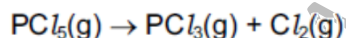


What is the order of **decreasing** size of the bond angles x, y and z?

	largest	→	smallest
A	x		y
B	x		z
C	y		z
D	z		y

w/09/qp11

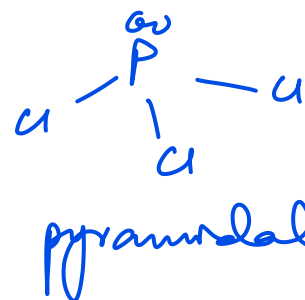
- 9 PCl_5 dissociates as follows.



The extent of dissociation is 13% at 160°C and 100% at 300°C.

Which pair of statements about this formation of PCl_3 is correct?

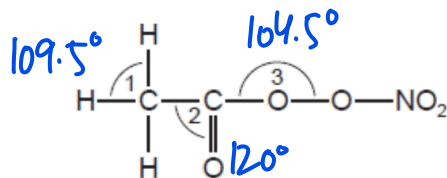
	shape of PCl_3 molecule	the reaction is
A	pyramidal ✓	endothermic ✓
B	pyramidal ✓	exothermic
C	trigonal	endothermic
D	trigonal	exothermic



w/09/qp11

- 7 Organic nitrates in photochemical smog can cause breathing difficulties.

The diagram shows an example of an organic nitrate molecule.



What is the correct order of the bond angles shown in ascending order (smallest first)?

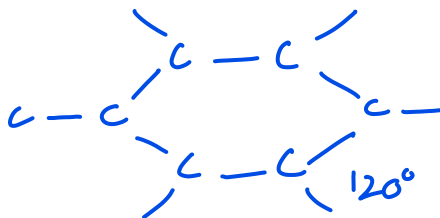
- A** 1 → 2 → 3 **B** 2 → 1 → 3 **C** 3 → 1 → 2 **D** 3 → 2 → 1

w/10/qp11

tetrahedral

10 Which molecule or structure does **not** contain three atoms bonded at an angle between 109° and 110° ?

- A ethanoic acid
 B graphite
 C propane
 D silicon(IV) oxide

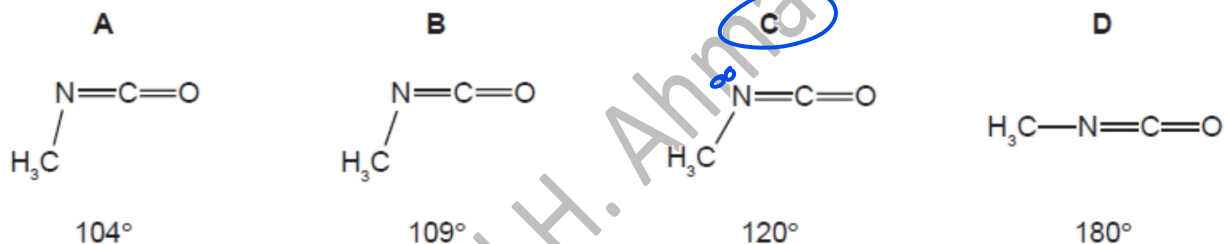


w/10/qp12

4 Methyl isocyanate, CH_3NCO , is a toxic liquid which is used in the manufacture of some pesticides.

In the methyl isocyanate molecule, the sequence of atoms is $\text{H}_3\text{C}-\text{N}=\text{C}=\text{O}$.

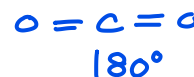
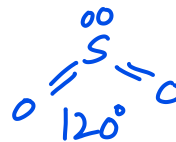
What is the approximate angle between the bonds formed by the N atom?



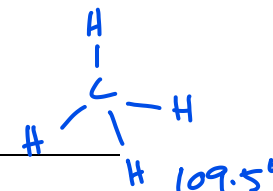
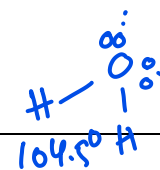
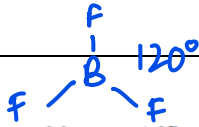
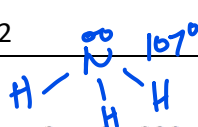
w/11/qp11

31 Which statements about bond angles are correct?

- ✓ 1 The bond angle in SO_2 is smaller than the bond angle in CO_2 .
- ✓ 2 The bond angle in H_2O is smaller than the bond angle in CH_4 .
- ✓ 3 The bond angle in NH_3 is smaller than the bond angle in BF_3 .



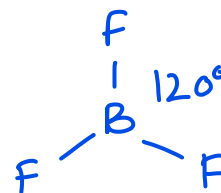
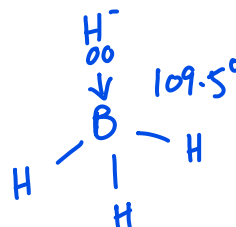
w/11/qp12



3 Sodium borohydride, NaBH_4 , and boron trifluoride, BF_3 , are compounds of boron.

What are the shapes around boron in the borohydride ion and in boron trifluoride?

	borohydride ion	boron trifluoride
A	square planar	pyramidal
B	square planar	trigonal planar
C	tetrahedral	pyramidal
D	tetrahedral	trigonal planar



w/12/qp11

12 In which pair do the molecules have the same shape as each other?

- A H₂O and CO₂
 B H₂O and SCl₂
 C NH₃ and BH₃
 D SCl₂ and BeCl₂



w/12/qp11

11 Which molecule is planar?

- A C₂Cl₄

- B C₃H₆

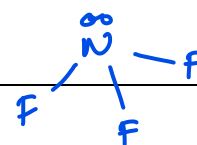
- C C₃H₈

- D NF₃

w/12/qp13

tetrahedral

tetrahedral

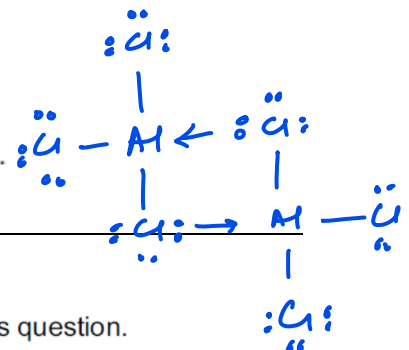


35 In the gas phase, aluminium chloride exists as the dimer, Al₂Cl₆.

By using this information, which of the following are structural features of the Al₂Cl₆ molecule?

- 1 Each aluminium atom is surrounded by four chlorine atoms. ✓
 2 There are twelve non-bonded electron pairs in the molecule. ✗
 3 Each aluminium atom contributes electrons to four covalent bonds. ✗

w/12/qp13



33 Valence shell electron pair repulsion theory should be used to answer this question.

Which species are trigonal planar?

- 1 BH₃ ✓
 2 CH₃⁺ ✓
 3 PH₃ ✗

s/13/qp11



10 X is an element in Period 2.

In which fluoride is the F-X-F angle the largest?

- A BF₃

- B CF₄

- C NF₃

- D OF₂

s/14/qp13

120°

109.5°

107°

104.5°

6 $AlCl_3$ vapour forms molecules with formula Al_2Cl_6 as it is cooled.

What happens to the bond angles during the change from $AlCl_3$ to Al_2Cl_6 ?

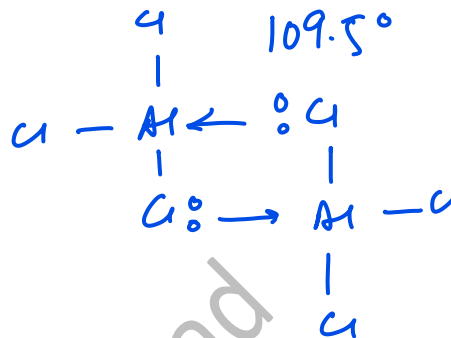
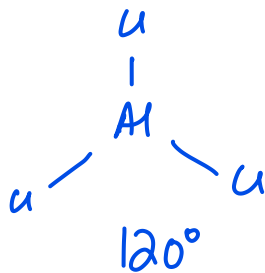
A Some decrease, some remain the same.

B Some increase, some remain the same.

C They all decrease. ✓

D They all increase.

s/14/qp11



Fahad H. Ahmad

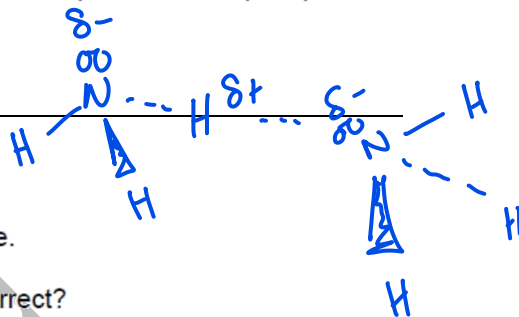
Intermolecular Forces: Permanent Dipoles, Van der Waals & Hydrogen Bonding

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.

s/18/qp13

*tendency to evaporate
low BP*



14 In this question, X represents an atom of chlorine, bromine or iodine.

Which explanation for the variation in volatility down Group 17 is correct?

- A Instantaneous dipole-induced dipole forces between molecules become stronger.
 B Permanent dipole-permanent dipole forces between molecules become stronger.
 C The bond energy of the X_2 molecules decreases.
 D The first ionisation energy $\text{X}(\text{g}) \rightarrow \text{X}^+(\text{g}) + \text{e}^-$ decreases.

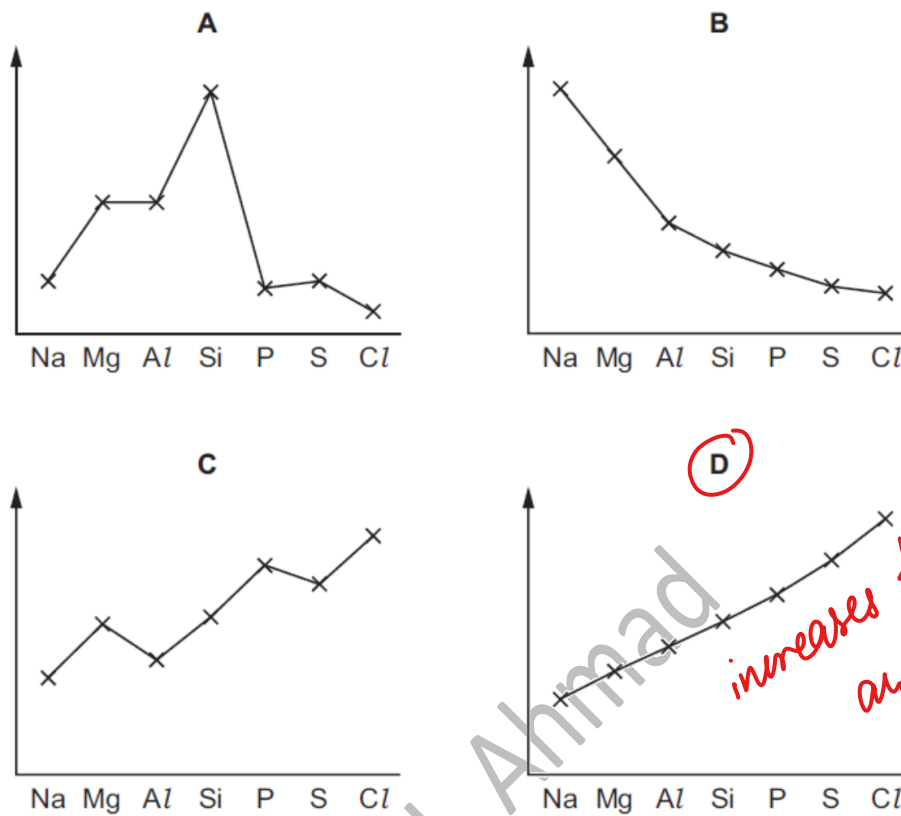
s/18/qp12

*Cl-Cl nonpolar
Br-Br only
I-I van der waals*

*bigger
more e-
more VDW*

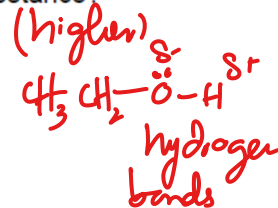
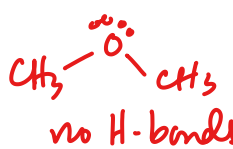
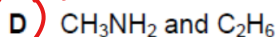
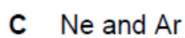
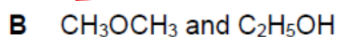
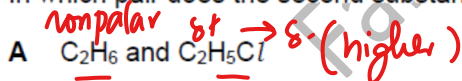
13 The graphs show trends in four physical properties of elements in Period 3, excluding argon.

Which graph has electronegativity on the y-axis?



s/18/qp12

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



s/18/qp12

both have van der waals or is bigger / more van der waals

32 Which statements are correct?

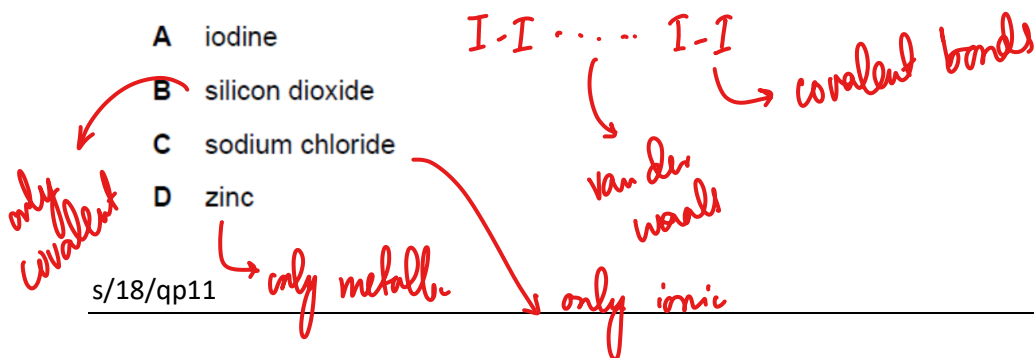
- 1 The hydrogen bonds in ice are more regularly arranged than in water. ✓
- 2 The solidification of water to form ice is exothermic. ✓
- 3 Pure water is less dense than ice. X

ice is less dense \propto $\frac{\text{mass}}{\text{volume}}$ increases

s/18/qp11

6 Which solid contains more than one type of bonding?

- A iodine
- B silicon dioxide
- C sodium chloride
- D zinc

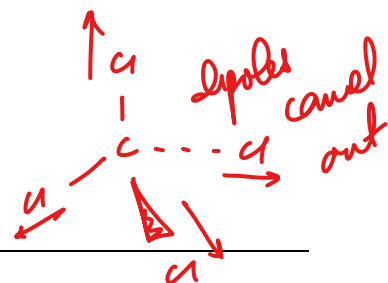
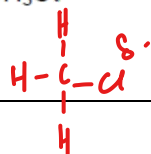


s/18/qp11

5 Which molecule has no overall dipole?

- A CH₃Cl
- B CH₂Cl₂
- C CHCl₃
- D CCl₄**

s/18/qp11



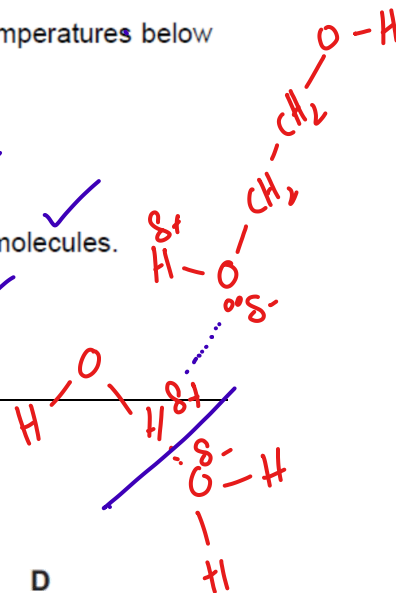
33 Ethylene glycol, HOCH₂CH₂OH, is used as a de-icer. It allows ice to melt at temperatures below 0°C.

Which statements are correct?

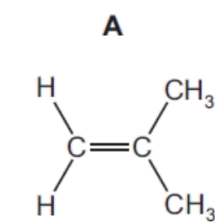
- 1 Ethylene glycol changes the extensive network of hydrogen bonds in ice. ✓
- 2 Ethylene glycol molecules form hydrogen bonds with other ethylene glycol molecules. ✓
- 3 Ethylene glycol molecules will dissolve in the water formed from the ice. ✓

s/17/qp13

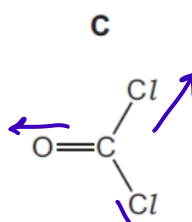
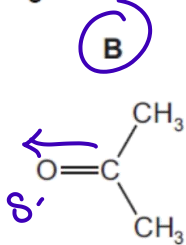
form H-bonds with each other



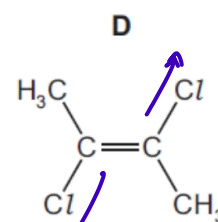
5 Which molecule has the largest overall dipole?



no dipoles



dipoles cancel out



s/17/qp11

- 32 Water has some unusual physical properties compared to other hydrides of Group 16 elements. Some of these properties are due to hydrogen bonds. These intermolecular forces are much stronger in water than they are in H_2S , for example.

Which statements are correct?

- 1 Hydrogen bonds cause the melting point of ice to be higher than expected. ✓
- 2 Hydrogen bonds cause the surface tension of water to be higher than expected. ✓
- 3 Hydrogen bonds cause the viscosity of water to be higher than expected. ✓

s/16/qp13

- 7 At room temperature and pressure, H_2O is a liquid and H_2S is a gas.

What is the reason for this difference?

- A O has higher first and second ionisation energies than S.
- B The covalent bond between O and H is stronger than the covalent bond between S and H.
- C** There is significant hydrogen bonding between H_2O molecules but not between H_2S molecules.
- D The instantaneous dipole-induced dipole forces between H_2O molecules are stronger than the instantaneous dipole-induced dipole forces between H_2S molecules.

s/16/qp11

- 34 Which physical properties are due to hydrogen bonding between water molecules?

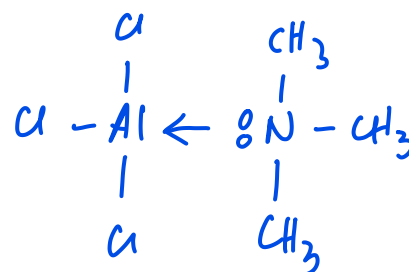
- 1 Water has a higher boiling point than H_2S . ✓
- 2 Ice floats on water. ✓
- 3 The $\text{H}-\text{O}-\text{H}$ bond angle in water is approximately 104° . ✗

s/15/qp13

- 14 The compound $(\text{CH}_3)_3\text{NAlCl}_3$ has a simple molecular structure.

Which statement about $(\text{CH}_3)_3\text{NAlCl}_3$ is correct?

- A $(\text{CH}_3)_3\text{NAlCl}_3$ molecules attract each other by hydrogen bonds.
- B** The Al atom has an incomplete valence shell of electrons.
- C The bonds around the Al atom are planar.
- D The molecules contain coordinate and covalent bonding



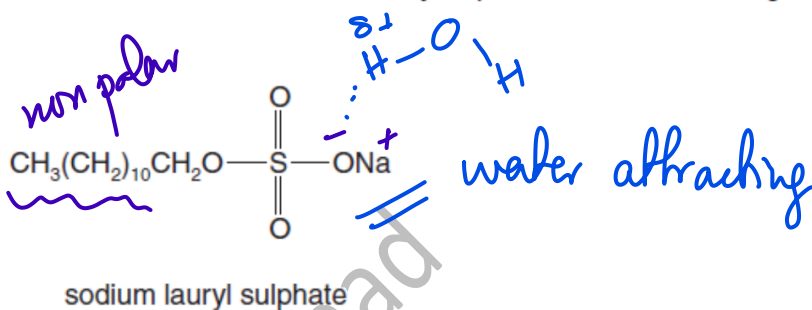
s/15/qp13

32 Why does aluminium chloride, Al_2Cl_6 , sublime at the relatively low temperature of $180^\circ C$?

- 1 The intermolecular forces between the Al_2Cl_6 molecules are weak. ✓
- 2 The co-ordinate bonds between aluminium and chlorine are weak. ✓
- ~~3~~ The covalent bonds between aluminium and chlorine are weak.

s/15/qp12

32 Long-chain alkanes are converted on an industrial scale into alkylsulphates for use as detergents, e.g. sodium lauryl sulphate.



What deductions about the properties of this substance can be made from this structure?

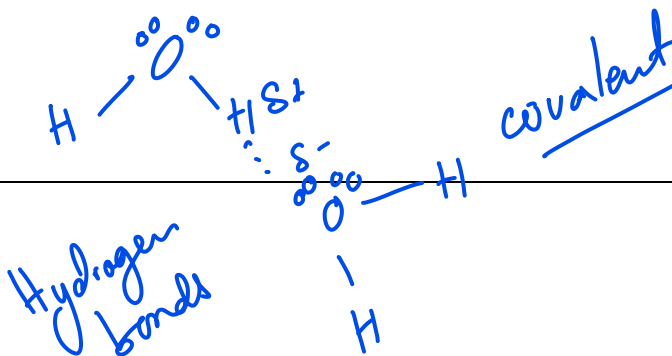
- 1 Part of the structure is polar and is water-attracting. ✓
- 2 The alkyl chain is soluble in oil droplets. ✓ *non polar attracts non polar*
- 3 All the C-C-C bond angles are tetrahedral.

s/03/qp1

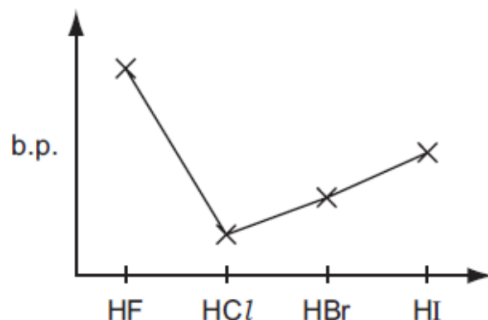
7 Which solid exhibits more than one kind of chemical bonding?

- A brass
- B copper
- C diamond
- D ice

s/04/qp1



5 The diagram shows the variation of the boiling points of the hydrogen halides.



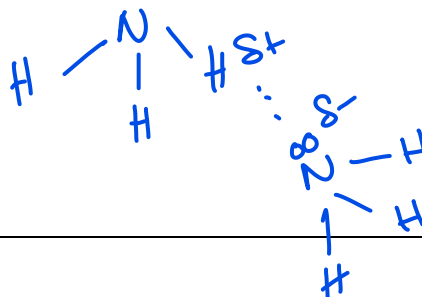
What explains the higher boiling point of hydrogen fluoride?

- A The bond energy of HF molecules is greater than in other hydrogen halides.
- B The effect of nuclear shielding is much reduced in fluorine which polarises the HF molecule.
- C The electronegativity of fluorine is much higher than for other elements in the group.
- D** There is hydrogen bonding between HF molecules.

s/05/qp1

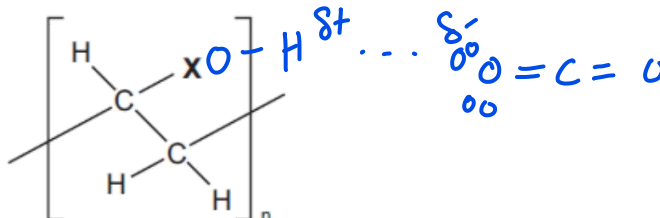
5 In which process are hydrogen bonds broken?

- A $\text{H}_2(\text{l}) \rightarrow \text{H}_2(\text{g})$
- B** $\text{NH}_3(\text{l}) \rightarrow \text{NH}_3(\text{g})$
- C $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
- D $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g})$



s/06/qp1

6 Plastic bottles for 'fizzy drinks' are made from a polymer with the following structure.



The ability of the polymer to prevent escape of carbon dioxide through the wall of the bottle depends on the ability of the group **X** to form hydrogen bonds with the carbon dioxide in the drink.

Which group **X** best prevents loss of carbon dioxide?

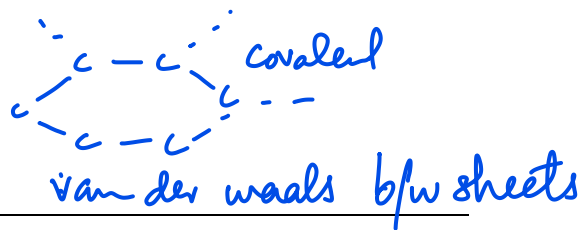
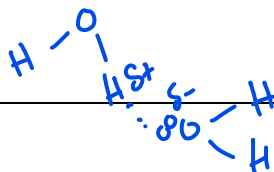
- A Cl
- B CN
- C CO_2CH_3
- D** OH

s/07/qp1

32 Which of the following solids contain more than one type of chemical bond?

- 1 brass (an alloy of copper and zinc)
 2 graphite
 3 ice

s/07/qp1



5 Which statement explains why the boiling point of methane is higher than that of neon?
 [Ar: H, 1; C, 12; Ne, 20]

- A A molecule of methane has a greater mass than a molecule of neon.
 B Molecules of methane form hydrogen bonds, but those of neon do not.
 C Molecules of methane have stronger intermolecular forces than those of neon. ✓
 D The molecule of methane is polar, but that of neon is not.

s/09/qp1

7 A crystal of iodine produces a purple vapour when gently heated.

Which pair of statements correctly describes this process?

	type of bond broken	formula of purple species
A	covalent	I
B	covalent	I ₂
C	induced dipole-dipole	I ₂
D	permanent dipole-dipole	I ₂

s/09/qp1

11 In which change would only van der Waals' forces have to be overcome?

- A evaporation of ethanol $C_2H_5OH(l) \rightarrow C_2H_5OH(g)$
 B melting of ice $H_2O(s) \rightarrow H_2O(l)$
 C melting of solid carbon dioxide $CO_2(s) \rightarrow CO_2(l)$ $O=C=O \dots \dots O=C=O$
 D solidification of butane $C_4H_{10}(l) \rightarrow C_4H_{10}(s)$ non polar

s/11/qp11

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

Which element is likely to have an electronegativity similar to that of aluminium?

- A barium
- B beryllium**
- C magnesium
- D strontium

diagonal elements have similar electronegativity

s/11/qp12

34 What is involved when a hydrogen bond is formed between two molecules?

- 1 a hydrogen atom bonded to an atom ~~less~~ electronegative than itself
- 2 a lone pair of electrons ✓
- 3 an electrostatic attraction between opposite charges ✓

s/11/qp12

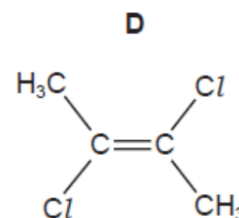
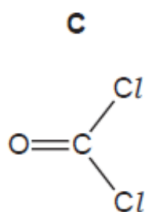
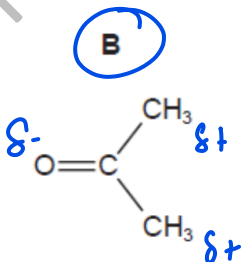
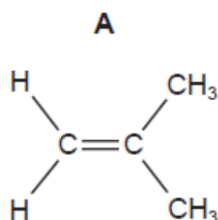
5 Which solid contains more than one kind of bonding?

- A iodine**
- B silicon dioxide
- C sodium chloride
- D zinc

vander waals
| - | . . . | - |
covalent
bond

s/12/qp12

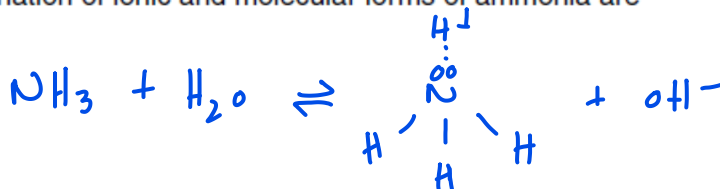
10 Which molecule has the largest overall dipole?



s/12/qp12

18 In a solution of ammonia in water, what combination of ionic and molecular forms of ammonia are present?

- A ions only
- B ions and simple molecules only
- C simple molecules and hydrogen-bonded molecules only
- D simple molecules, hydrogen-bonded molecules and ions**



w/03/qp1

- 6 The gecko, a small lizard, can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads at its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing.

What is the attraction between the gecko's toe pads and the glass surface?

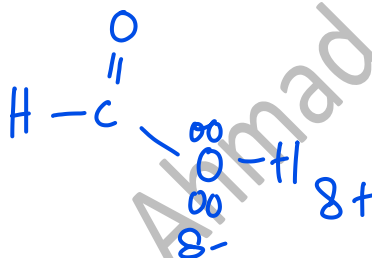
- A co-ordinate bonds
 B covalent bonds
 C ionic bonds
 D van der Waals' forces

increased surface area, more van der Waals

w/04/qp1

- 4 Which compound has a boiling point which is influenced by hydrogen bonding?

- A CH_3CHO
 B CH_3OCH_3
 C HCO_2H
 D HCO_2CH_3

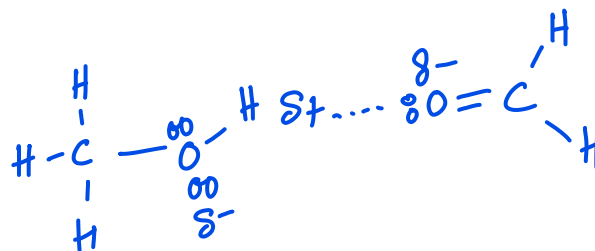


w/05/qp1

- 5 Hydrogen bonding can occur between molecules of methanal, HCHO , and molecules of liquid Y.

What could liquid Y be?

- A CH_3OH
 B CH_3CHO
 C CH_3COCH_3
 D $\text{CH}_3\text{CO}_2\text{CH}_3$



w/07/qp1

- 5 Which quantity would best indicate the relative strengths of the hydrogen bonds between the molecules in liquid hydrogen halides?

- A bond dissociation energies
 B enthalpy changes of solution
 C enthalpy changes of formation
 D enthalpy changes of vaporisation

intermolecular forces \rightarrow melting, boiling

w/08/qp1

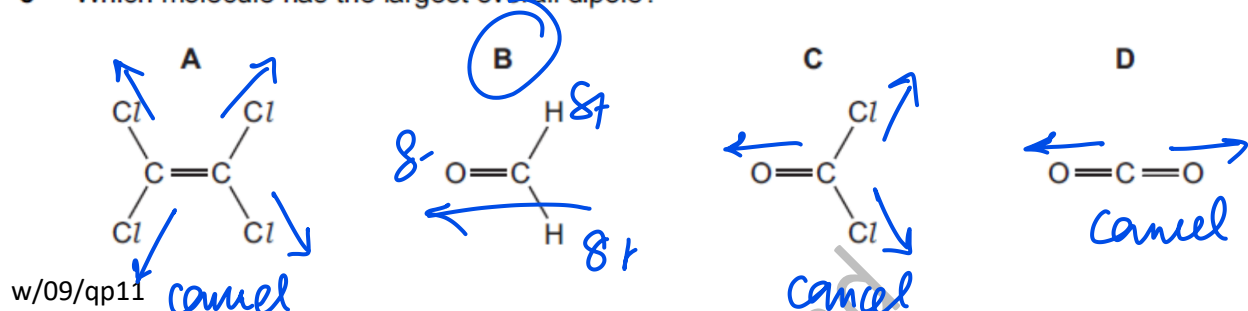
35 Chlorine is a greenish-yellow gas, bromine is a dark red liquid and iodine is a dark grey solid.

What causes these differences in volatility?

- 1 the halogen-halogen bond energy
- 2 the magnitude of the van der Waals' forces between the molecules ✓
- 3 the number of electrons in the halogen molecule ✓ more electrons, more van der waals

w/08/qp1

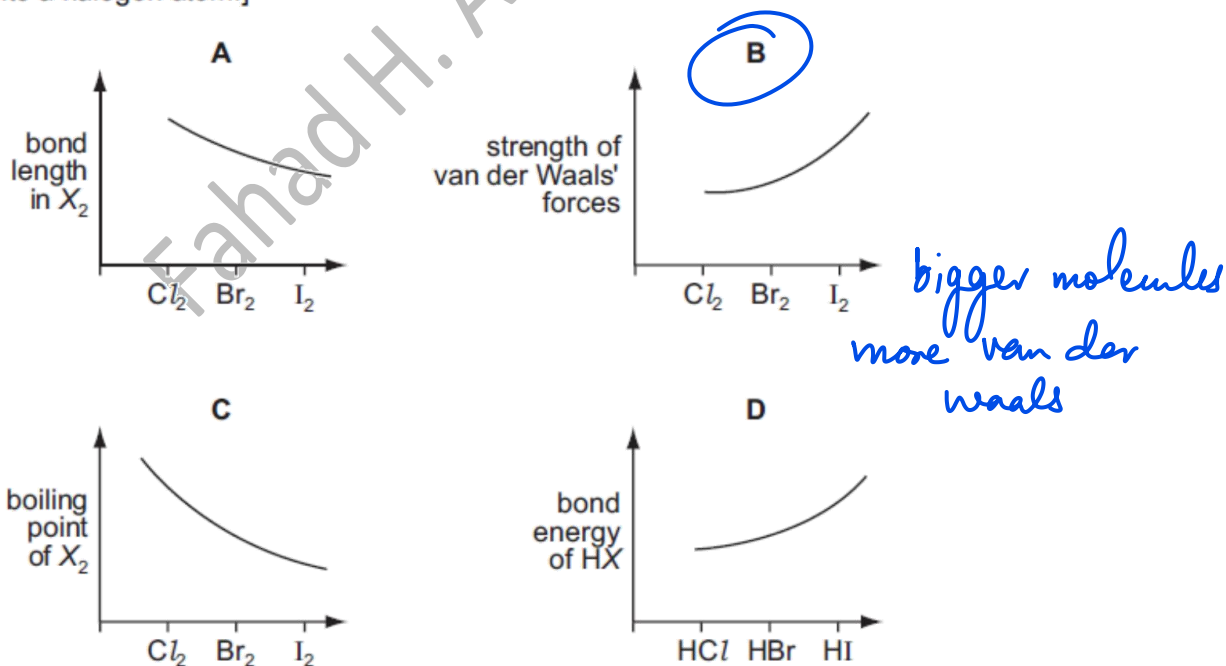
5 Which molecule has the largest overall dipole?



w/09/qp11

15 Which graph correctly describes a trend found in the halogen group?

[X represents a halogen atom.]



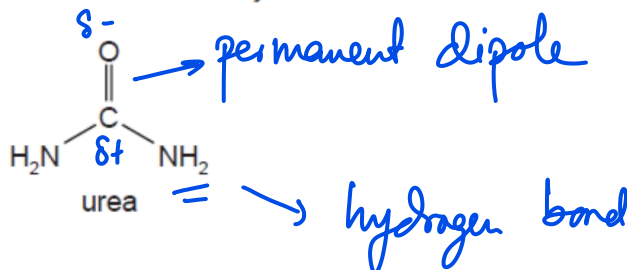
w/09/qp11

32 Which physical properties are due to hydrogen bonding between water molecules?

- 1 Water has a higher boiling point than H_2S . ✓
- 2 Ice floats on water. ✓
- 3 The H-O-H bond angle in water is approximately 104° . ✗ true but nothing to do with hydrogen bonding

w/09/qp11

33 Which types of intermolecular forces can exist between adjacent urea molecules?



- 1 hydrogen bonding ✓
- 2 permanent dipole-dipole forces ✓
- 3 temporary induced dipole-dipole forces → always present

w/10/qp11

1 The ability of an atom in a covalent bond to attract electrons to itself is called its electronegativity.

The greater the difference between the electronegativities of the two atoms in the bond, the more polar is the bond.

Which pair will form the most polar covalent bond between the atoms?

- A chlorine and bromine
- B chlorine and iodine
- C fluorine and chlorine
- D** fluorine and iodine



w/10/qp12

17 Why do the halogens become less volatile as Group VII is descended?

- A The halogen-halogen bond energy decreases.
- B The halogen-halogen bond length increases.
- C** The number of electrons in each molecule increases. → more van der Waals forces
- D The van der Waals' forces between molecules become weaker.

w/11/qp11

33 The three statements that follow are all true.

Which of these can be explained, at least in part, by reference to hydrogen bonding?

- 1 At 0 °C ice floats on water. ✓ → this has hydrogen bonding
- 2 The boiling point of propan-2-ol is 82 °C. The boiling point of propanone is 56 °C. ✓
- 3 At 20 °C propanone and propanal mix completely. ✗ they both don't have hydrogen bonds

w/11/qp11

32 Why does aluminium chloride, Al_2Cl_6 , sublime at the relatively low temperature of 180 °C?

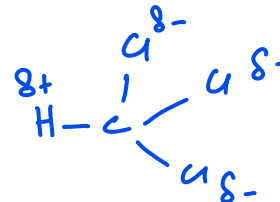
- 1 The intermolecular forces between the Al_2Cl_6 molecules are weak. ✓
- 2 The co-ordinate bonds between aluminium and chlorine are weak. ✓
- 3 The covalent bonds between aluminium and chlorine are weak. ✗ covalent bonds are not broken

w/11/qp11

5 The presence of dipoles helps to explain why the element Br_2 and the compound $CHCl_3$ exist as liquids at room temperature.

Which types of dipole are involved?

	Br_2	$CHCl_3$
A	induced dipoles and permanent dipoles ✓	induced dipoles and permanent dipoles ✓
B	induced dipoles and permanent dipoles ✓	induced dipoles only
C	induced dipoles only	induced dipoles and permanent dipoles
D	induced dipoles only	induced dipoles only

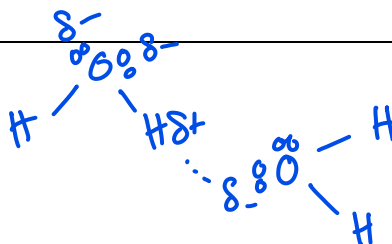


w/11/qp12

2 Which statement can be explained by intermolecular hydrogen bonding?

- A Butane has a higher boiling point than propane.
- B Hydrogen bromide forms an acidic solution when dissolved in water.
- C SiH_4 has a higher boiling point than CH_4 .
- D** Water has a higher boiling point than CH_4 .

w/12/qp13



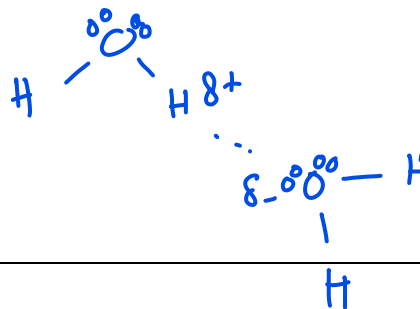
8 Which solid contains more than one kind of bonding?

A copper

B diamond

C ice *covalent + hydrogen bonding*

D magnesium oxide



w/13/qp13

9 Methylpropan-1-ol and butan-1-ol are structural isomers. Methylpropan-1-ol has a lower boiling point.

Which statement explains why the boiling point of methylpropan-1-ol is lower than that of butan-1-ol?

A Methylpropan-1-ol cannot form hydrogen bonds.

B Methylpropan-1-ol has weaker covalent bonds than butan-1-ol.

C Methylpropan-1-ol has weaker van der Waals' forces than butan-1-ol.

D Methylpropan-1-ol molecules have more surface area than butan-1-ol molecules.

longer chains have more surface area and more van der waals

w/14/qp11

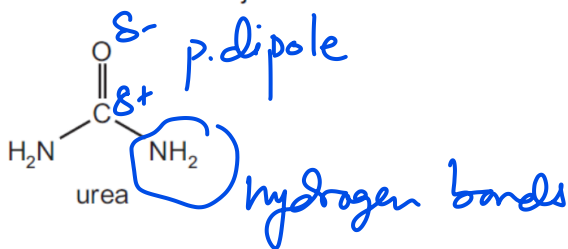
7 Copper and iodine are both shiny crystalline solids.

Which forces exist between particles in solid copper and between neighbouring iodine molecules in solid iodine?

	copper	iodine
A	ionic bonds	covalent bonds
B	ionic bonds	van der Waals' forces
C	metallic bonds ✓	covalent bonds
D	metallic bonds ✓	van der Waals' forces ✓

w/14/qp13

33 Which types of intermolecular forces can exist between adjacent urea molecules?



- 1 hydrogen bonding ✓
- 2 permanent dipole-dipole forces ✓
- 3 instantaneous dipole-induced dipole forces ✓ always present

w/14/qp13

32 P and Q are two liquid compounds with similar M_r values. Molecules of P attract each other by hydrogen bonds. Molecules of Q attract each other by van der Waals' forces only.

How do the properties of P and Q differ?

- 1 P has higher surface tension than Q. ✓
- 2 P has a higher boiling point than Q. ✓
- 3 P is less viscous than Q. ✗

s/14/qp13

31 P and Q are two compounds with similar M_r values. Molecules of P attract each other by hydrogen bonds. Molecules of Q attract each other by van der Waals' forces only.

A sample of liquid P is compared to a sample of liquid Q.

How will their properties differ?

- 1 P is more soluble in water than Q. ✓
- 2 P has a higher melting point than Q. ✓
- 3 P is more viscous than Q. ✓

s/14/qp12

14 What is the order of increasing melting point of the four chlorides shown?

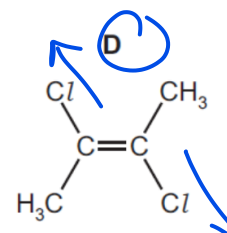
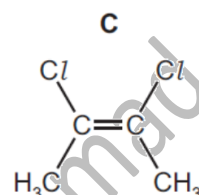
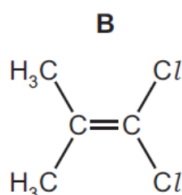
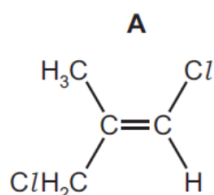
CCl_4 (l) HCl (g) $MgCl_2$ (ionic) PCl_5 (s)

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

chemical periodicity

s/14/qp11

9 Which molecular structure will have the **smallest** overall dipole?



cancel out

s/14/qp11

Bond Strength, Bond Length, Bond Polarity

36 Which statements explain why nitrogen gas is unreactive?

- 1 Nitrogen atoms are highly electronegative *true but does not explain*
- 2 Nitrogen molecules are non-polar.
- 3 The triple bond between nitrogen atoms is very strong.

w/17/qp11

13 Which element shows the greatest tendency to form covalent compounds?

- A boron *most electronegative*
- B magnesium
- C neon
- D potassium

w/16/qp12

32 The Group IV elements carbon, silicon and germanium can all exist in the giant molecular structure which is also found in diamond. The bond lengths in these structures are given below.

element X	C	Si	Ge
bond length, X-X / nm	0.154	0.234	0.244

Why does the bond length increase down the group?

- 1 Orbital overlap decreases down the group.
- 2 Atomic radius increases down the group.
- 3 Nuclear charge increases down the group.

w/15/qp11

6 Carbon and silicon have the same outer electronic structure.

Why is a Si-Si bond weaker than a C-C bond?

- A Silicon atoms have a larger atomic radius than carbon atoms.
- B Silicon has a greater nuclear charge than carbon.
- C Silicon has a smaller first ionisation energy than carbon.
- D Silicon is more metallic than carbon.

s/16/qp13

17 Which statement about the ammonium ion, NH_4^+ , is correct?

- A All bond angles are 107° .
 B Ammonium ions are formed when ammonia behaves as an acid.
 C Ammonium ions are unreactive when heated with NaOH(aq) .
 D The bonds are all the same length.



s/15/qp12

16 The volatility of the Group 17 elements, chlorine, bromine and iodine, decreases down the group.

What is responsible for this?

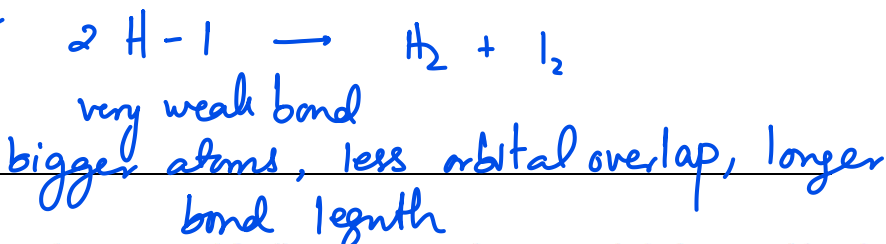
- A bond length in the halogen molecule
 B bond strength in the halogen molecule
 C electronegativity of the halogen
 D number of electrons in the halogen molecule

more e^-
 more van der Waals
 higher MP/BP

m/18/qp12

17 Which gaseous hydride most readily decomposes into its elements on contact with a hot glass rod?

- A ammonia
 B hydrogen chloride
 C hydrogen iodide
 D steam



s/03/qp1

34 Which of the following statements are correct for the sequence of compounds below considered from left to right?

NaF MgO AlN SiC

- 1 The electronegativity difference between the elements in each compound increases. ✗
 2 The formula-units of these compounds are isoelectronic (have the same number of electrons). ✓
 3 The bonding becomes increasingly covalent. ✓

s/03/qp1

less difference in electronegativity, covalent

14 Which ion is most polarising?

- A Al^{3+}
 B Ba^{2+}
 C Mg^{2+}
 D Na^+

*Smaller ion
greater charge } higher charge density*

s/04/qp1

23 Dichlorodifluoromethane, CCl_2F_2 , has been used in aerosol propellants and as a refrigerant.

Which statement helps to explain why dichlorodifluoromethane is chemically inert?

- A The carbon-fluorine bond energy is large.
 B The carbon-fluorine bond has a low polarity.
 C Fluorine is highly electronegative.
 D Fluorine compounds are non-flammable.

→ doesn't attract other molecules

s/05/qp1

31 The Group IV elements carbon, silicon and germanium all exist in a diamond structure. The bond lengths in these structures are given below.

element X	C	Si	Ge
bond length X-X/nm	0.154	0.234	0.244

Why does the bond length increase down the group?

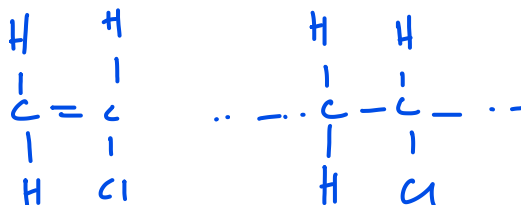
- 1 Orbital overlap decreases down the group. ✓
 2 Atomic radius increases down the group. ✓
 3 Nuclear charge increases down the group. ✗

s/06/qp1

23 Polymerisation of chloroethene gives PVC.

How does the carbon-carbon bond in PVC compare with that in chloroethene?

- A longer and stronger
 B longer and weaker
 C shorter and stronger
 D shorter and weaker



s/09/qp1

*→ single bonds are weaker
less attraction, so longer as well.*

35 Compared with the HCl molecule, the bondX..... of the HBr molecule isY.....

Which pairs of words correctly complete the above sentence?

	X	Y
1	energy	less
2	polarity	less
3	length	greater

bigger atoms, weaker bonds.
 electronegativity decreases
 bigger atom

s/12/qp12

19 Nitrogen is frequently used as an inert atmosphere because it is an unreactive gas.

Which is the best explanation of this unreactivity?

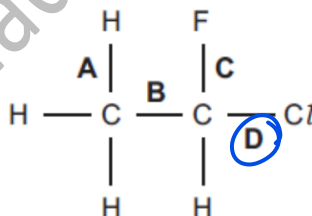
- A Its molecule contains a triple bond.
- B** The bond energy of the molecule is high (994 kJ mol⁻¹).
- C The bond in its molecule is very short (0.110 nm).
- D The three p orbitals of nitrogen are half-filled.

w/03/qp1

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

Which of the bonds in the structure below has the lowest bond energy?

- C-F 340
- C-C 350
- C-H 416

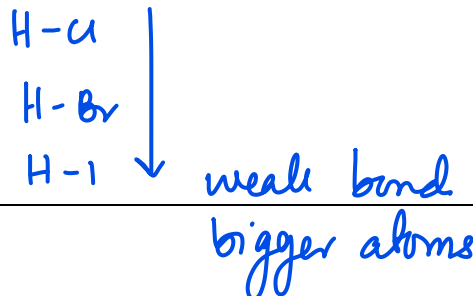


C-F is not know but its bond energy will be higher than.
 C-Cl / smaller atom

w/04/qp1

36 Which properties in the sequence hydrogen chloride, hydrogen bromide and hydrogen iodide steadily increase?

- 1 thermal stability ✓
- 2 bond length ✓
- 3 ease of oxidation ✓



w/04/qp1

- 22 In the upper atmosphere chlorofluoroalkanes (CFCs) are broken down to give chlorine radicals but not fluorine radicals.

What is the best explanation for this?

- A Fluorine is more electronegative than chlorine.
B Fluorine radicals are less stable than chlorine radicals.
 C The C-F bond is stronger than the C-Cl bond. *smaller atom, stronger bonds*
D The chlorine atom is larger than the fluorine atom.

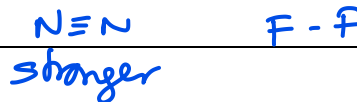
w/05/qp1

- 18 Gaseous nitrogen is less reactive than gaseous fluorine.

What is the reason for this difference in reactivity?

- A The boiling point of nitrogen is lower than that of fluorine.
B The relative molecular mass of nitrogen is lower than that of fluorine.
C The atomic radius of nitrogen is greater than that of fluorine.
 D The bond strength in the molecule is greater in nitrogen than in fluorine.

w/07/qp1



- 25 Chlorofluoroalkanes, CFCs, can be used as refrigerants, aerosol propellants and fire extinguishers.

CFCs such as CCl_3F and CCl_2F_2 are more stable than chloroalkanes such as CCl_4 .

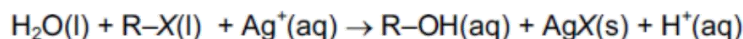
What is the reason for their greater stability?

- A Fluorine has a higher first ionisation energy than chlorine.
B Fluorine radicals are more stable than chlorine radicals.
 C The C-F bond energy is larger than the C-Cl bond energy.
D The C-F bond is more polar than the C-Cl bond.

w/07/qp1

- 23 Four drops of 1-chlorobutane, 1-bromobutane and 1-iodobutane were put separately into three test-tubes containing 1.0 cm^3 of aqueous silver nitrate at 60°C .

A hydrolysis reaction occurred. (R represents the butane chain C_4H_9- and X the halogen atom.)



The rate of formation of cloudiness in the tubes was in the order $\text{RCI} < \text{RBr} < \text{RI}$.

Why is this?

- A The R-X bond polarity decreases from RCI to RI.
 B The solubility of AgX(s) decreases from AgCI to AgI.
 C The ionisation energy of the halogen decreases from CI to I.

D The bond energy of R-X decreases from RCI to RI.

*c-i bond breaks easily
 bigger atom / weak bonds
 so AgI ppt forms quickly*

w/08/qp1

- 25 Chlorofluorocarbons, CFCs, can be used as refrigerants, aerosol propellants and fire extinguishers.

CFCs such as CCl_3F and CCl_2F_2 are more stable than chloroalkanes such as CCl_4 .

What is the reason for their greater stability?

- A Fluorine has a higher first ionisation energy than chlorine.
 B Fluorine radicals are more stable than chlorine radicals.
 C The C-F bond energy is larger than the C-Cl bond energy.
 D The C-F bond is more polar than the C-Cl bond.

w/13/qp13

- 35 On being heated, hydrogen iodide breaks down more quickly than hydrogen chloride.

Which statements explain this faster rate?

- 1 The HI bond is weaker than the HCl bond. ✓
 2 The reaction of the breakdown of HI has a smaller activation energy than that of HCl. ✓
 3 The breakdown of HI is more exothermic than that of HCl. ✗

w/14/qp11

→ overall ΔH does not affect rate

30 Polymerisation of ethene gives poly(ethene).

How does the carbon-carbon bond in poly(ethene) compare with that in ethene?

- A The carbon-carbon bond is longer and stronger in poly(ethene).
- B The carbon-carbon bond is longer and weaker in poly(ethene).
- C The carbon-carbon bond is shorter and stronger in poly(ethene).
- D The carbon-carbon bond is shorter and weaker in poly(ethene).

s/13/qp12

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