SECTION A (20 marks)

1.	B	2.	C	3.	C	4.	D	5.	D
6.	B	7.	A	8.	B	9.	D	10.	A
11.	A	12.	B	13.	A	14.	D	15.	A
16.	B	17.	B	18.	B	19.	B	20.	D

Brief comments on Answers in Section A

Question 1
The charges are irrelevant for the number of neutrons. The atomic numbers can be found from the Periodic Table.

Co has 27 protons and therefore 57 – 27 = 30 neutrons
Fe has 26 protons and therefore 58 – 26 = 32 neutrons
Mn has 25 protons and therefore 56 – 25 = 31 neutrons
Ni has 28 protons and therefore 56 – 28 = 28 neutrons

The $^{58}Fe^{3+}$ has the highest number of neutrons. **Answer: B**

Question 2
Rutherford used alpha particle radiation. Alpha particles are helium nuclei. **Answer: C**

Question 3
Bohr, not Rutherford, suggested that electrons move in discrete energy levels or shells.
Answer: C

Question 4
From **right to left**, core charge decreases so first ionisation energy decreases and the atoms are less able to attract electrons from other atoms so the electronegativity decreases too. **Answer: D**

Question 5
$_3Li$ has electron configuration of $1s^2 2s^1$. The valence electron is the $2s^1$. **Answer: D**

Question 6
The first element in the 3d transition series, $_{21}Sc$, has the electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{3d^1 4s^2}$ with the valence electrons highlighted. Sc^{3+} will lose all of the valence electrons to form Sc^{3+} with electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6$. This means there are 5 occupied subshells. **Answer: B**

Question 7
W has the properties of a network covalent substance.
X looks to be ionic – conducts in the molten state.
Y low mp and lack of any conductivity suggests it is molecular.
Z mp and conductivity in solid and molten state suggests it is metallic. **Answer: A**

Question 8
PH_3 is similar to NH_3. It has three bonding pairs and one lone pair in the valence shell around the P atom. **Answer: B**

Question 9
The delocalised valence electrons move with the deformation of the cation arrangement to maintain bonding. **Answer: D**

Question10
Ionic substances have directional bonding which makes them brittle not malleable. **Answer: A**

Question 11
CH_2Cl_2 has two polar bonds and the dipoles do not sum to zero. It is therefore polar.
CH_4 has non-polar bonds and is therefore non-polar.
C_2H_6 has non-polar bonds and is therefore non-polar.
Cl_2 has a non-polar bond as the atoms have the same electronegativity, and is therefore non-polar. **Answer: A**

Question 12
$n(O_2) = 32 / 32 = 1.0$ mol ie. 6 0 x 10^{23} molecules. **Answer: B**

Question 13
Butanoic acid has the semi-structural formula $CH_3CH_2CH_2COOH$. Therefore there are 8 H atoms. **Answer: A**

Question 14
P and Q are more likely metals and would form an alloy.
R and S are non-metals and would share electrons in covalent bonds.
Answer: D

Question 15
$n(Cu) = m/M = 2.12 / 63.5 = 3.34 \times 10^{-2}$ mol $\quad n(O) = m/M = 0.53 / 16.0 = 3.31 \times 10^{-2}$ mol

$n(Cu) : n(O) = 3.34 \times 10^{-2} : 3.31 \times 10^{-2} = 1.00 : 1.01$ ie 1:1

The empirical formula is CuO. **Answer: A**

Question 16
$n(Na_3PO_4) = m/M = 1.64 / 164 = 0.0100$ mol

$n(Na^+) : n(Na_3PO_4) = 3:1 \quad n(Na^+) = 3 \times 0.0100 = 0.0300$ mol. **Answer: B**

Question 17
$n(CH_4) = m/M = 2.00 / 16.0 = 0.125$ mol

$n(H) = 4\ n(CH_4) = 4 \times 0.125 = 0.500$ mol

$N(H) = n \times N_A = 0.500 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ atoms **Answer: B**

Question 18
There are only three structural isomers
$CH_3CH_2CH_2CH_2CH_3$ or pentane
$CH_3CH(CH_3)CH_2CH_3$ or 2-methylbutane
$CH_3C(CH_3)_2CH_3$ or dimethylpropane **Answer: B**

Question 19
Both CH_3CH_2OH and $CH_3CH_2NH_2$ are polar and will have H-bonds between molecules. $CH_3CH_2CH_3$ and $CH_3CH_2CH_2CH_3$ are non-polar and will only exhibit dispersion forces between molecules but $CH_3CH_2CH_3$ has a lower electron count and therefore has weaker dispersion forces between molecules. **Answer: B**

Question 20
To form an addition polymer the molecule must have a C/C double bond. A, B and C all have this feature but D only has C/C single bonds. **Answer: D**

SECTION B

Question 1 (6 marks)

a. Fe_2O_3 **(1 mark)**

b. $n(Fe_2O_3) = m/M = 2.394 / 159.6$ **(1 mark)** $= 0.01500$ mol **(1 mark)**

c. $n(O^{2-}) = 3 \times n(Fe_2O_3)$ **(1 mark)** $= 3 \times 0.01500 = 0.04500$ mol **(1 mark)**

d. $N(O^{2-}) = n \times N_A = 0.04500 \times 6.02 \times 10^{23} = 2.71 \times 10^{22}$ **(1 mark)**

Question 2 (7 marks)

a. $$A_r(Fe) = \frac{\%_1 RIM_1 + \%_2 RIM_2 + \%_3 RIM_3}{100}$$

$$A_r(Fe) = \frac{5.95 \times 54 + 91.88 \times 56 + 2.17 \times 57}{100}$$ **(1 mark)**

$A_r(Fe) = 55.90$ **(1 mark)**

b. The Relative Isotopic Mass values have been approximated to the mass numbers **(1 mark)**

c. **i.** Iron consists of a network lattice of iron cations **(1 mark)** in a sea of delocalised valence electrons **(1 mark)**

ii. Conductivity – the sea of delocalised valence electrons responds to an applied electric field **(1 mark)**
Malleability – the delocalised electrons move with any deformation of the cations to maintain bonding **(1 mark)**

Question 3 (7 marks)

a. **i.** Atoms are
contained
ii. Atoms of t
isotopes –

ns have been shown to be
oms **(1 mark)**.
ecause of the presence of
umber of neutrons **(1 mark)**.

Refer to later page for answer.

b. **i.** Emission li
energy leve
energy **(1 r**
spectrum (1

ng been excited into higher
off discrete amounts of
ength in the emission

ii. any two of:
- electrons
- electrons
- an electr
- other rea

f charge

Question 4 (5 marks)

a. Assume 100

Refer to later page for answer.

ark)

ark)

The empir

b. The mass (

88 **(1 mark)**

176 / 88 = 2 The molecular formula is $C_6H_8O_6$ **(1 mark)**

Question 5 (5 marks)

a. An empirical formula is the simplest possible ratio of atoms in a formula. The formula $C_{19}H_{38}O$ cannot be simplified further **(1 mark)**.

b. $M(C_{19}H_{38}O) = 19 \times 12.0 + 38 \times 1.0 + 16.0 = 282 \text{ g mol}^{-1}$ **(1 mark)**

$n(C_{19}H_{38}O) = m / M = 1.0 \times 10^{-12} / 282 = 3.55 \times 10^{-15}$ **(1 mark)**

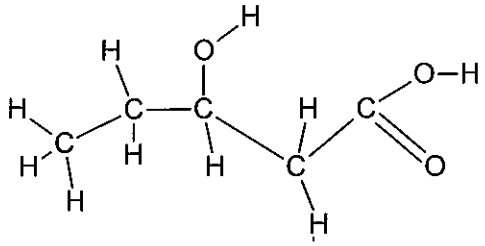
$N(C_{19}H_{38}O) = n \times N_A = 3.55 \times 10^{-15} \times 6.02 \times 10^{23} = 2.1 \times 10^{9}$ **(1 mark)**

c. Number of insects $= 6.02 \times 10^{23} / 2.1 \times 10^{9} = 2.9 \times 10^{14}$ **(1 mark)**

Question 6 (7 marks)

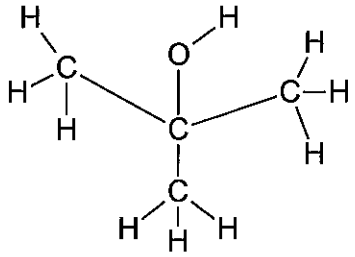
a.
i. 2-pentene or pent-2-ene **(1 mark)**
ii. 1-butanol or butan-1-ol **(1 mark)**
iii. propanoic acid **(1 mark)**
iv. hexan-1-amine or 1-hexanamine **(1 mark)**
v. 3-methylpent-2-ene **(1 mark)**

b. **i.**



(1 mark)

ii.



(1 mark)

Question 7 (9 marks)

a. Core charge is the effective nuclear charge **(1 mark)**. It is calculated by subtracting the number of inner shell electrons from the nuclear charge **(1 mark)**.

b. The core charge increases from left to right across each period **(1 mark)**. Across the period the nuclear charge increases but the number of inner shell electrons is constant **(1 mark)**.

c. The atoms become smaller in size **(1 mark)** as the core charge increases and electrons are held more tightly **(1 mark)**.

d. **i.** The removal of the valence electrons from a metal means that one less shell is occupied **(1 mark)** and the remaining electrons are held more tightly **(1 mark)**.

ii. The addition of electrons to an atom means that the electrons must be held less strongly and so the atom size increases **(1 mark)**. (The outer electrons would also repel each other more strongly. This results in atoms increasing in size.)

Question 8 (9 marks)

a. Empirical formula of potassium fluoride is KF **(1 mark)**

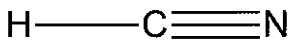
b. The formula of magnesium fluoride is MgF_2 **(1 mark)** and since it has a ratio of cations to anions of 1:2 it could not have the same structure **(1 mark)**. (There must be some justification to get the second mark.)

c. KF is ionic **(1 mark)** and the bonds between ions are strong electrostatic attractions **(1 mark)** which gives KF a relatively high melting point.
Tetrafluoromethane is non-polar molecular **(1 mark)** and only has dispersion forces acting between molecules **(1 mark)** (which are unable to hold the molecules together at room temperature.)

d. In the solid state, the ions are locked into their lattice positions **(1 mark)** and cannot respond to an applied electric field. In the molten state, the ions have some freedom to move and can respond to an applied electric field **(1 mark)**.

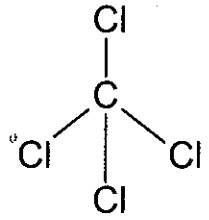
Question 9 (9 marks)

a. HCN is linear **(1 mark)**



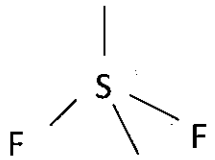
(1 mark)

CCl_4 is tetrahedral **(1 mark)**



(1 mark)

SF_2 is angular or v-shaped **(1 mark)**



(1 mark)

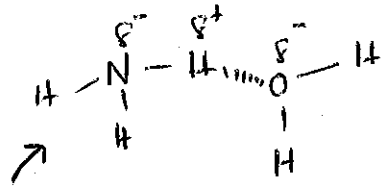
b. HCN is polar. It has a polar (C-N) bond and lacks symmetry **(1 mark)**.
CCl_4 is non-polar. It has four polar (C-Cl) bonds but is symmetrical and so the sum of the dipoles is zero **(1 mark)**.
SF_2 is polar. It has two polar (S-F) bonds and lacks symmetry **(1 mark)**.

Question 10 (8 marks)

CO_2 is made up of m Refer to later ılar **(1 mark)** and at room
temperature any disp page for nolecules together **(1 mark)**,
so it a gas at room te answer.
SiO_2 is a continuous ular structure. The Si atoms
are covalently bonde shion and each O atom is
covalently bonded to ıg covalent bonding makes it a
solid substance with a).

NS

Question 3



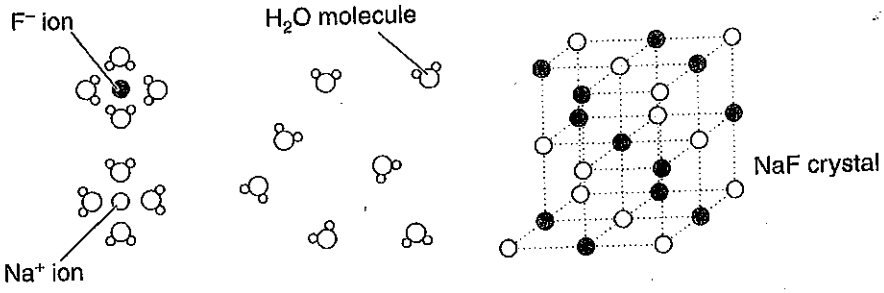
a. With the aid of a labelled diagram, explain clearly why ammonia dissolves in water.

NH_3 can dissolve due to its ability to hydrogen bond with water. 2 marks

b. Would you expect methane (CH_4) to dissolve in water? Explain your answer.

As CH_4 is non-polar it can only form dispersion forces and can't H-bond with water so will not be able to dissolve. 2 marks

C. The diagram below shows a simplified model of the process of dissolving NaF in the water.



i. Name the type of bonds which must be broken in the sodium fluoride crystal if it is to dissolve. ionic

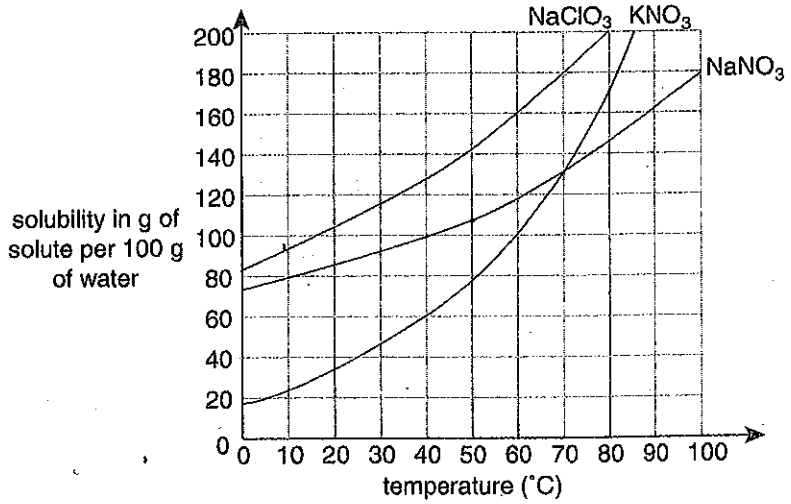
ii. Name the type of bonds which form between the Na^+ ion and the water molecules. ion-dipole

iii. Name the types of bonds formed between water molecules. H-bonds

iv. Suggest why sodium fluoride would be added to water supplies.

To add fluoride (F^-) to the water supply to prevent tooth decay. 1 + 1 + 1 + 1 = 4 marks

The graph below shows solubility curves for three metal salts: potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$) and sodium chlorate ($NaClO_3$).



Where necessary, assume that the density of water = 1 g mL^{-1}.

d. At what temperature would 90 g of $NaNO_3$ saturate 100 mL of water? 30°C 1 mark

e. 100 mL of a saturated solution of KNO_3 was cooled from 70°C to 40°C. What mass of KNO_3 would be expected to crystallise out of the solution?

@ 70°C = 130g @ 40°C = 60g 130 − 60 = 70g. 2 marks

f. 60 g portions of each salt are placed into separate beakers. 50 g of water is added to each beaker, and the beakers heated to 50°C. In which beaker (or beakers) will all of the salt dissolve? Clearly show your working.

$NaNO_3$ = 52.5g /50g $NaClO_3$ = 70g /50g

KNO_3 = 40g /50g As $NaClO_3$ can hold up to 70g if 60g were put in all would dissolve. 3 marks

Total 14 marks

Question 4

a. Ethylene glycol is a compound often used as an antifreeze in cars in cold weather. It is an organic compound known to contain 38.7% carbon and 9.7% hydrogen. The remainder is oxygen.

Calculate the empirical formula of ethylene glycol.

C	H	O	
$\frac{38.7}{12}$	$\frac{9.7}{1}$	$\frac{51.6}{16}$	
3.225	9.7	3.225	CH_3O
1	3	1	

3 marks

b. If the molecular mass of ethylene glycol is found to be 62, calculate its molecular formula.

$M(CH_3O) = 31$

$62/31 = 2 \quad \therefore C_2H_6O_2$

2 marks

Total 5 marks

Question 5

Pheromones are a special type of compound secreted by the females of many insect species to attract males for mating. One pheromone has the molecular formula $C_{19}H_{38}O$. Normally the amount of this pheromone secreted by a female insect is about 1.0×10^{-12} g.

a. Explain why $C_{19}H_{38}O$ is both an empirical formula and a molecular formula.

1 mark

b. Determine the approximate number of molecules of a pheromone in each female insect.

3 marks

c. Approximately how many female insects would be needed to provide 1.0 mol of pheromone molecules?

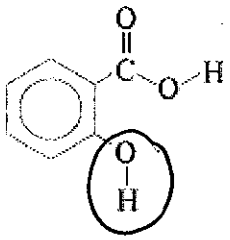
1 mark

Total 5 marks

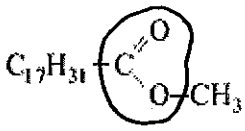
Question 10.

i. Correctly circle the functional groups named in each molecule below.

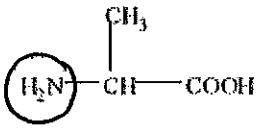
a. Hydroxyl (alcohol)



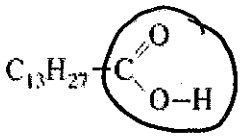
b. Ester.



c. Amine

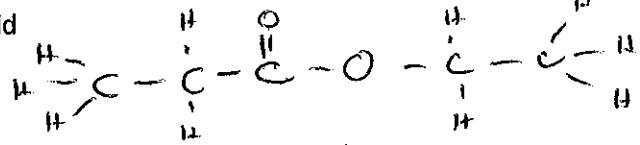


d. Carboxyl (carboxylic acid)



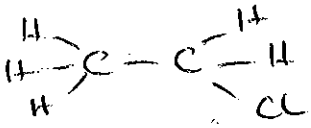
ii. Draw and name the product(s) of the following reactions.

a. Ethanol and Propanoic Acid



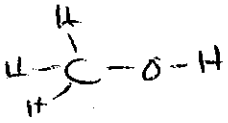
ethyl propanoate.

b. Ethene and HCl



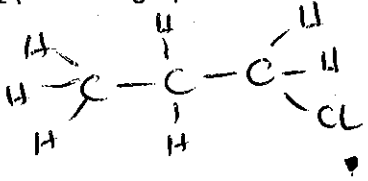
chloroethane.

c. Chloromethane and NaOH



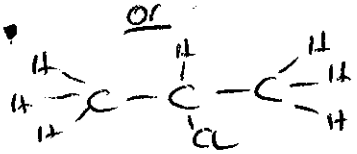
methanol

d. Propane and Cl_2 (with uv light)



1-chloropropane

or



2-chloropropane.