IB Chemistry HL
Topic4 Answers

1. C

2. A

3. C

4. C
5. D

6. C

7. B

8. D
9. D

10. B

11. A

12. C

13. C

14. B

15. B

16. A

17. B

18. C

19. D

20. (a) mixing/joining together/combining/merging of atomic orbitals to form molecular orbitals/new orbitals/orbitals of equal energy; 1

Accept specific example such as mixing of s and p orbitals.

(b) sp;

Do not award mark if sp^2 or sp^3 is also stated.

one sigma and two pi (bonds); 2

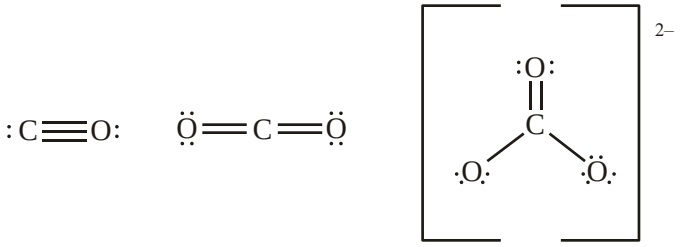
(c) (σ bond formed by) end-on/axial overlap;
electrons/electron density between the two (carbon) atoms/*OWTTE*;
(π bond formed by) sideways/parallel overlap;
electrons/electron density above and below σ bond/*OWTTE*; 4

Marks can be scored from a suitable diagram.

Do not award 2^{nd} and 4^{th} marks if electrons are not mentioned.

[7]

21. (i)



OTTWE 3

*Award **[1]** each. Need charge on CO_3^{2-} for **[1]**.*
Penalize missing lone electron pairs only once.

(ii) CO_3^{2-};
bond order $1\frac{1}{3}/1\frac{1}{3}$ bonds each compared to double bonds in CO_2 and triple bond in CO;
the fewer the number of bonding electrons, the less tightly nuclei are held together, the longer the bond; 3

[6]

22. (i) "head on" overlap of (2) orbitals;
along axial symmetry/along a line drawn through the 2 nuclei/*OWTTE*; 2
Accept suitable diagram for 2nd mark.

(ii) parallel p orbitals overlap sideways on;
above and below the line drawn through the 2 nuclei/*OWTTE*; 2
Accept suitable diagram for 2nd mark.

(iii) 1 σ and 1 π/σ and π; 1

(iv) 1 σ and 2 π/σ and π; 1

[6]

23. (i) OF_2
sp^3;
V-shaped/bent/angular;
2 bonding + 2 non-bonding (electron pairs); 3

(ii) H_2CO
sp^2;
trigonal planar;
2 areas of electron density/negative charge centres; 3

(iii) C_2H_2
sp;
linear;

2 areas of electron density/negative charge centres; 3

Accept suitable diagrams for shapes.

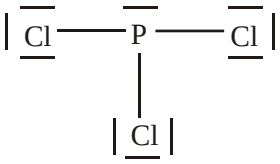
*Allow **[2]** for ECF if correct explanation given for incorrect formula, e.g. C_2H_4.*

[9]

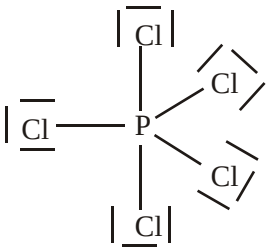
24. (i)

*Award **[1]** for each correct Lewis structure.*

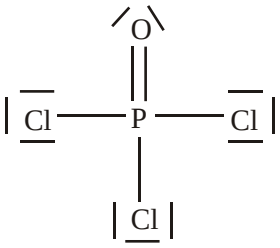
PCl_3



PCl_5



$POCl_3$



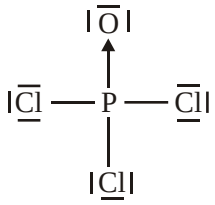
3

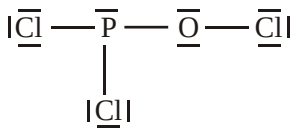
Accept use of dots or crosses to represent electron pairs.

*Subtract **[1]** if non-bonding pair on P in PCl_3 is missing.*

*Subtract **[1]** if non-bonding pair(s) on Cl or O are missing.*

Accept legitimate alternatives for $POCl_3$, e.g. see below.





(ii)

PCl_3	PCl_5	$POCl_3$
trigonal pyramid;	trigonal bipyramid;	tetrahedral;
Accept answers in range 100° to 108°;	90° **and** 120°;	*Accept answers in range* 100° to 112°;

Allow ECF if based on legitimate chemical structure. 6

(iii)

PCl_3	PCl_5	$POCl_3$
polar, polarities do not cancel/OWTTE;	non-polar, polarities cancel/OWTTE;	polar, polarities do not cancel/OWTTE;

3

*Award **[2]** for three polarities correct, **[1]** for two polarities correct, and **[1]** for correct reason(s).*

Accept argument based on dipole moments.

Allow ECF if based on legitimate chemical structure.

[12]

25. (i) combining of atomic orbitals to form new orbitals/*OWTTE*; 1

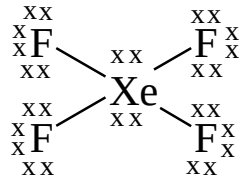
(ii) σ : overlap of orbitals between nuclei/end-on overlap;
π : overlap above and below line joining nuclei/sideways overlap;
*Award **[1]** if candidate counts bonds (8 σ, 1 π), or describes all three types of bonds (i.e. C—H is σ, C—C is σ, C=C is σ and π).*

single bonds longer than double;
double bonds stronger than single;

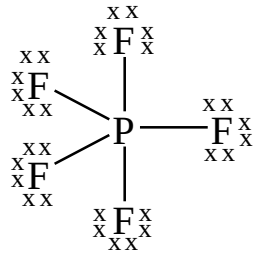
C of CH_3 is sp^3;
other two C are sp^2; 6
Accept suitable diagrams.

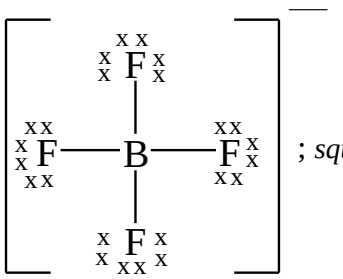
[7]

26. (a) 3



; lone pairs on Xe required for the mark.





; square brackets and charge required for the mark.

Accept any combination of dots, crosses and lines.
Penalise missing fluorine lone pairs once only.

(b) XeF_4
Square planar and 90°;
PF_5
trigonal bipyramid and 90° and 120°;
BF_4^-
Tetrahedral and 109.5°/109°; 3

Allow <u>clear</u> suitable diagrams instead of name.
No ECF from (a).

[6]

27. (a) hybridization: mixing/merging of atomic orbitals;
N_2 –sp;

N_2H_2 –sp^2;

N_2H_4 –sp^3; 4

(b) σ bonds (result from the) overlapping of orbitals end to end/along inter-nuclear

axis;
π bonds (result from the) overlapping of parallel/sideways p orbitals;
(single bonds) σ bonds only;
(double bonds) have a σ bond and a π bond; 4

Suitable clear and labelled diagrams acceptable for all marks.

[8]

28. (i) electron removed from higher energy level/further from nucleus/greater atomic radius;

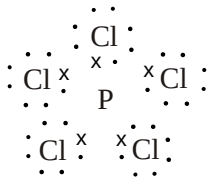
increased repulsion by extra inner shell electrons/increased shielding effect; 2

(ii) $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e$;

(even though) valence electrons in the same shell/main energy level/ Mg^{2+} has noble gas configuration;
Mg has greater nuclear/core charge/more protons; 3

[5]

29. (i)

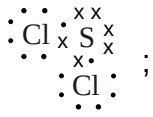


;

trigonal bipyramidal;
90°;
120°;
180°; 3

*Award **[1]** for 2 correct bond angles.*

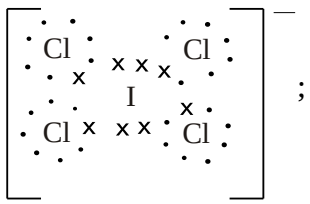
(ii)



;

Bent/angular/V-shaped;
100°–107°; 3

(iii)



;

square planar; 3

90°;
No ECF allowed.
Penalize once only ***[1]*** *mark for missing lone pairs.*
Accept structures using lines to represent bonding and lone electron pairs.

[9]

30. (a) (i) mixing/combining of atomic orbitals/OWTTE; 1

(ii) C_{60} *fullerene*: sp^2;

graphite : sp^2;

diamond: sp^3; 3

(iii) each carbon atom is bound to 3 other carbon atoms/π bonding;
leading to delocalized electrons; 2

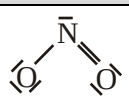
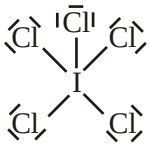
(b) (i) sigma/σ bonds are formed by orbitals overlapping end to end/ along the internuclear axis/along line directly between nuclei;
Accept suitable diagram.

pi/π bonds are formed by p orbitals overlapping sideways; 2
Accept suitable diagram.

(ii) 12 sigma bonds;
2 pi bonds; 2

[10]

31. (i)

Species	*Lewis (electron-dot) structure*	*Shape*	*Bond angle(s)*
NO_2^-	 ;	Bent/V-shaped/angular;	109.5° < θ < 120°;
ICl_5	 ;	Square pyramidal;	|Inplane Cl-I-out-of-plane Cl| < 90°; *Allow corresponding correct statement for other correctly identified bond angles.*
SF_4	 ;	See-saw;	|Equatorial F-S-Equatorial F| < 120°; *Allow corresponding correct statement for axial-equatorial and axial-axial F-S-F angles.*

9

Accept crosses and dots for electrons in the Lewis structures

also.
If all ideal bond angles are given, penalize once only.
As the Lewis structures were asked for, and not 3D representations, do not penalize incorrectly drawn geometries.

(ii) (equatorial F-S-equatorial F) less than 120° since non-bonding electron pairs (exert greater repulsive forces and thus) compress the bond angles/*OWTTE;* 1

(iii) orbital diagram representation of carbon ground-state going to carbon excited-state electron configuration;
mixing of orbitals to give three new entirely equivalent hybrid orbitals, sp^2, on each carbon;
sp^2 orbitals trigonal (triangular) planar in shape;
unhybridized orbitals overlap to give π-bond; 4

(iv) sp^2;
both N-O bond lengths equal, (intermediate between double and single bonds) due to resonance/delocalisation; 2

(v) O-H is most polar;
O-H has greatest difference between electronegativities/calculation showing values of 1.4, 0.5 and 0.9 respectively; 2

[18]