DK014
Chemistry 1
Semester I
2025/2026
2 hours

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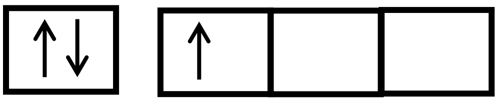
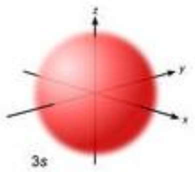
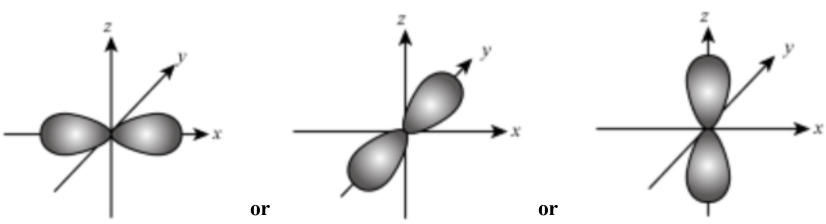
SUGGESTED ANSWER
SMARTCHEM

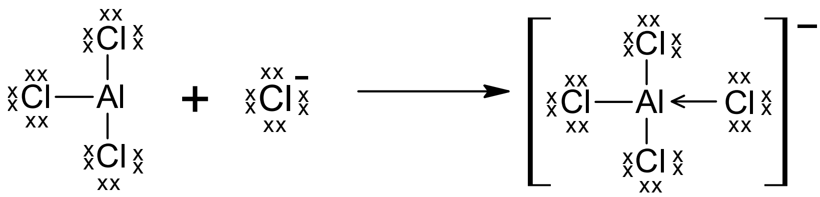
No.	Part	Suggested Answers	Marks	
1	(a)	At STP condition, 1 mol gas ≡ 22.4 L		
		Mol of H_2 gas = 5.00 L / 22.4 L mol^{-1} = 0.2232 mol	1	M1
		From balanced equation,		
		3 mol H_2 ≡ 2 mol NH_3		
		0.223 mol H_2 ≡ (2 x 0.223 mol)/3 mol NH_3	1	M2
		= 0.1488 mol		
		Number of NH_3 molecules = 0.149 mol x 6.02 x 10^{23}		
		= 8.96 x 10^{22} molecules	1	M3
	(b)	Mass of C = (12.0/44.0) x 3.96 g = 1.08 g C		
		Mass of H = (2(1.0)/18.0) x 0.72 g = 0.080 g H	1	M4
		Mass of O = 1.80 g - (1.08 + 0.080) g = 0.64 g	1	M5

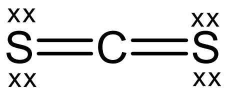
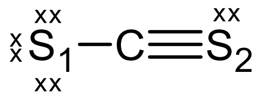
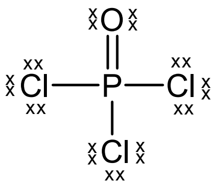
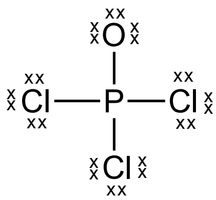
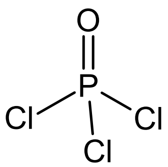
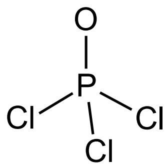
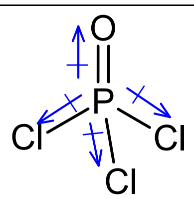
Element	C	H	O
Mass (g)	1.08	0.080	0.64
n (mol)	1.08/12.0 = 0.090	0.080/ 1.0 = 0.080	0.64/ 16.0 = 0.040
Simplest ratio	0.090/0.040 = 2.25 2.25 x 4 = **9**	0.080/0.040 = 2 2 x 4 = **8**	0.040/0.040 = 1 1 x 4 = **4**

			Marks	
		n (mol) row	1	M6
		Simplest ratio row	1	M7
		Empirical formula = $C_9H_8O_4$	1	M8

	(c) (i)	Mass solution = mass solute + mass solvent = 20.0 g + 80.0 g = 100.0 g % by mass = (mass solute/mass solution) x 100% = (20.0 g/ 100.0 g) x 100% = 20.0%	1 1	M9 M10
	(c) (ii)	Mole of solute (NaOH) = 20.0 g/ 40.0 = 0.50 mol Volume solution = mass solution/density solution = 100.0 g/ 1.10 gmL^{-1} @ = 90.91 mL @ 0.09091 L Molarity = mol solute / volume solution (L) @ = 0.50 mol/ 0.09091 L = 5.50 mol L^{-1}	1 1 1 1	M11 M12 M13 M14
	(d)(i)	n_{Al} = 15.0 g/ 27.0 = 0.5556 mol (given) n_{Cl_2}= 30.0L/ 22.4 = 1.339 mol (given) From equation, 2 mol Al ≡ 3 mol Cl_2 0.5556 mol ≡ (3 x 0.5556)/2 mol Cl_2 = 0.8334 mol Cl_2 (needed) n_{Cl_2} (needed) < n_{Cl_2}(given). Cl_2 is an excess reactant Al is a limiting reactant.	1 1 1 1	M15 M16 M17 M18
	(d)(ii)	From equation, 2 mol Al ≡ 2 mol $AlCl_3$ 0.5556 mol Al ≡ 0.5556 mol $AlCl_3$ Theoretical mass of $AlCl_3$ = 0.5556 mol x (27.0 + 3(35.5)) = 74.17 g	1 1	M19 M20

		Percentage yield = (actual yield/ theoretical yield) x 100 @ = (45.0 g / 74.17 g) x 100 = 60.7 %	1 1	M21 M22
		TOTAL	**22**	
2	(a)(i)	Electronic configuration of A: **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$**	1	M1
	(a)(ii)	Set of quantum numbers of 4th electron: ***(n=2, l=0, m=0, s=+1/2)* OR *(n=2, l=0, m=0, s=-1/2)*** Set of quantum numbers of 13th electron: ***(n=3, l=1, m=+1, s=+1/2)* OR *(n=3, l=1, m=+1, s=-1/2)* OR** ***(n=3, l=1, m=0, s=+1/2)* OR *(n=3, l=1, m=0, s=-1/2)* OR** ***(n=3, l=1, m=-1, s=+1/2)* OR *(n=3, l=1, m=-1, s=-1/2)***	1 1	M2 M3
	(a)(iii)	Valence orbital diagram:  3s 3p	1	M4
	(a)(iv)	**A^{3+}**	1	M5
	(a)(v)	  $3p_x$ $3p_y$ $3p_z$	1 1	M6 M7
	(b)	$3d_{xy}$	1	M8
	(c)(i)	Aufbau Principle. Electron must be filled into lower energy orbital (3p) before start filling into a higher energy orbital (4s).	1 1	M9 M10
		TOTAL	**10**	

3	(a)	Element D **Period 4, Group 2** Element E **Period 4, Group 14**	 1 1	 M1 M2
	(b)	- **D^+ ion is formed when one electron is removed from D atom**. @ Number of electrons of D^+ ion is less than D atom. - **Proton number of D atom and D^+ ion remain the same**. - **The repulsion between remaining electrons in D^+ ion is weaker than that in D atom**. - **The attraction between nucleus and the remaining electrons in D^+ ion is stronger than that in D atom**. @ Electrons cloud in D^+ ion shrank. - Therefore, **size of D^+ ion is smaller than that of D atom**.	1 1 1 1	M3 M4 M5 M6
	(c)	- **The effective nuclear charge of E atom is higher than D atom**. @ - **The attraction between nucleus and valence electrons in E atom is greater than in D atom**. - Hence**, more energy is needed to remove valence electrons from E than D.**	1 1	M7 M8
		TOTAL	**8**	
4	(a)	 **Cl^- ion shares one of its lone pairs to Al atom in $AlCl_3$ to form dative bond**. @ Cl is a donor because it has lone pairs and Al is an acceptor because it has an empty orbital.	Reactants – 1 Product & dative bond – 1 1	M1 M2 M3
	(b)	C – 4 valence e 2 x S – 12 valence e 16	1	M4

<table>
<tr><td></td><td></td><td>
<table>
<tr><th>Structure I</th><th>Structure II</th></tr>
<tr><td></td><td></td></tr>
<tr><td>C : 4 – 0 – 4 = 0
S : 6 – 4 – 2 = 0</td><td>C : 4 – 0 – 4 = 0
S_1 : 6 – 6 – 1 = –1
S_2 : 6 – 2 – 3 = +1</td></tr>
</table>
Structure I is the most plausible.
Reason : formal charge of each atom equals to zero.
</td><td>1 + 1
1 + 1
1
1</td><td>M5
M6
M7
M8
M9
M10</td></tr>
<tr><td></td><td>(c)(i)</td><td>Lewis structure :
 OR 
4 bonding pairs around central atom / AB$_4$
According to VSEPR theory, the strength of repulsion between bonding pairs are equal.
 OR 
Molecular shape: Tetrahedral</td><td>1
1
1
1</td><td>M11
M12
M13
M14</td></tr>
<tr><td></td><td>(c)(ii)</td><td>
OR
Cl atom is more electronegative than P atom, therefore P-Cl bond is polar.
O atom is more electronegative than P atom, therefore P-O bond is polar.</td><td>1</td><td>M15</td></tr>
</table>

		Bond dipoles cannot cancel each other @ **Dipole moment, $\mu \neq 0$** The **molecule is polar**.	1 1	M16 M17
	(c)(iii)	**Dipole-dipole interaction** / dipole dipole forces	1	M18
	(d)	The valence electrons in magnesium metal are **delocalised in the sea of electrons.** The **electrons are free to move and can carry heat from the hotter part to the cooler part** of the metal.	1 1	M19 M20
TOTAL			**20**	
5	(a)	$K_c = [PH_3][BCl_3]$ $1.8 \times 10^{-3} = x^2$ $[PH_3] = [BCl_3] = 0.0424$ M	1 1 1	M1 M2 M3
	(b)	(see table below)		
TOTAL			**10**	

	$2POCl_3(g)$ $\rightleftharpoons$	$2PCl_3(g)$ +	$O_2(g)$	Marks	
$P_{initial}$ (atm)	0.565	0	0	1	M4
P_{change} (atm)	$-2x$	$+2x$	$+x$	1	M5
$P_{equilibrium}$ (atm)	$= 0.565-2x$ = 0.097 atm	$2x$ =0.468 atm	x 0.234 atm	1	M6

$P_{O_2} = x = 0.234$ atm — 1 — M7

$$K_p = \frac{(P_{PCl_3})^2 P_{O_2}}{(P_{POCl_3})^2}$$ — 1 — M8

$$= \frac{(0.468)^2(0.234)}{(0.097)^2}$$ — 1 — M9

$= 5.45$ — 1 — M10

6	(a)(i)	$CH_3COOH\,(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$	1	M1
	(a)(ii)	H_3COOH acid — CH_3COO^- conjugate base	1	M2
		H_2O base — H_3O^+ conjugate acid	1	M3

(b)

	$PO_4^{3-}(aq)$ +	$H_2O(l) \rightleftharpoons$	$HPO_4^{2-}(aq)$ +	$OH^-(aq)$
[ ]initial (M)	0.50 M		0	0
[ ]change (M)	$-x$		$+x$	$+x$
[ ]equilibrium (M)	0.50 M$-x$		x	x

1 M4

1 M5

$$K_b = \frac{[HPO_4^{2-}][OH^-]}{[PO_4^{3-}]}$$

1 M6

$$5.9\times10^{-3} = \frac{x^2}{0.50 - x}$$

1 M7

x = 0.0514 M = [OH⁻]

1 M8

$$\begin{aligned} pOH &= -\log[OH^-] \\ &= -\log(0.0514) \\ &= 1.29 \end{aligned}$$

1 M9

$$\begin{aligned} pH + pOH &= 14.00 \\ pH + 1.29 &= 14.00 \\ pH &= 12.71 \end{aligned}$$

1 M10

TOTAL	**10**