

I(1):

1) has an electron configuration of 2,8 (or $1s^2 2s^2 2p^6 3s^2$)

2) has an electron configuration of 2,8 (or $1s^2 2s^2 2p^6 3s^2$)

3) has an electron configuration of 2,8 (or $1s^2 2s^2 2p^6 3s^2$)

4) has an electron configuration of 2,8,18 (or $1s^2 2s^2 2p^6 3s^2 3p^6$)

I(2):

2)

Note: Common non-volatile acids are H_2SO_4 , H_3PO_4 and lactic acid ($CH_3CHOHCOOH$).

I(3):

1) HCl contains only the H-Cl bond, which is a single bond.

2) H_2SO_4 contains H-O, S-O and S=O bonds, where all of them are not triple bonds.

3) HCN contains $C\equiv N$ triple bond.

4) Formic acid, $HCOOH$ contains H-C, C=O, C-O and O-H bonds, where all of them are not triple bonds.

I(4):

- 1) F_2 is a gas under standard conditions.
 - 2) Cl_2 is a gas under standard conditions.
 - 3) Br_2 is a liquid (but easily vapourise) under standard conditions.
 - 4) I_2 is a solid (but easily sublimate) under standard conditions.
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I(5):

- 1) True.*
- 2) Sodium metal reacts with water vapour in the air readily.
- 3) True.
- 4) True.

*We do not need to know specifically which lattice structure sodium has. Among common metals, the only two crystalline metals that have a hexagonal shape are magnesium and zinc. (In fact, all group I metals have a body-centered lattice, which accounted for their low densities.)

I(6):

- 1) $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$ (redox)
- 2) $N_2 + 3H_2 \rightarrow 2NH_3$ (Haber process)
- 3) $H_2NCONH_2 + H_2O \rightarrow CO_2 + 2NH_3$ (urea decomposition)
- 4) $Ca(OH)_2 + 2NH_4Cl \rightarrow CaCl_2 + NH_3 + 2H_2O$ (double displacement)

I(7):

- 1) The slopes of the gas-solid boundary for all substances are positive.
- 2) The gas-liquid boundary extends to the critical point.
- 3) The solid-liquid boundary of water is negative, though all other substances are positive.

4) True.

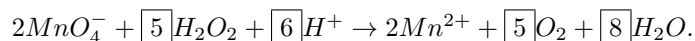
II:

(1): Consider the half equations:

For the reduced side, we have $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$.

For the oxidised side, we have $H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$.

Combine the above, we have the full equation



(2): We have the half equations:

For the reduced side, we have $H_2O_2 + 2e^- \rightarrow 2OH^-$.

For the oxidised side, we have $Mn^{2+} + 4OH^- \rightarrow MnO_2 + 2H_2O + 2e^-$.

Combine the above, we have the full equation $Mn^{2+} + H_2O_2 + 2OH^- \rightarrow MnO_2 + 2H_2O$.

III:

(1): Referring to the table:

Chemical	HA	H^+	A^-
Concentration before equilibrium	C	0	0
Concentration after equilibrium	$C - \alpha C$	αC	αC

Therefore, $K_a = \frac{(\alpha C)(\alpha C)}{C(1-\alpha)} = \boxed{\frac{\alpha^2 C}{1-\alpha}}$.

(2): A^- ions in NaA salt dissociate completely. Therefore, we have:

Chemical	HA	H^+	A^-
Concentration before equilibrium	C	0	0
Concentration after equilibrium	$C - [H^+]$	$[H^+]$	$C_{salt} + [H^+]$

As HA is a weak acid, we have $C \gg H^+$ and $C_{salt} \gg [H^+]$. By the provided

approximation, we have $[HA] = C$ and $[A^-] = C_{salt}$.

Therefore, we have $K_a = \frac{[H^+]C_{salt}}{C}$, i.e. $[H^+] = \boxed{\frac{K_a C}{C_{salt}}}$.

IV:

(1): Cations that can produce precipitate with Cl^- ion are $Ca^{2+}, Ba^{2+}, Pb^{2+}$ and Ag^+ .

As Ca belongs to period 3, Ba belongs to period 4, Ag belongs to period 5 and Pb belongs to period 6, we have (a) is silver and (b) is lead.

(2): Trivalent cations that can produce precipitate with $NH_3(aq)$ are Fe^{3+} and Al^{3+} .

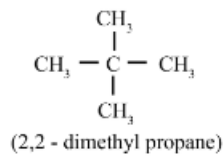
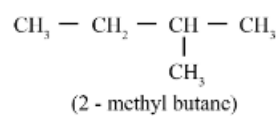
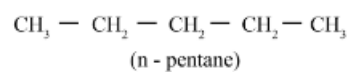
When $NaOH(aq)$ is added, the precipitate $Al(OH)_3$ redissolves as $NaAl(OH)_4$.

Therefore, (c) is aluminium and (d) is iron.

V:

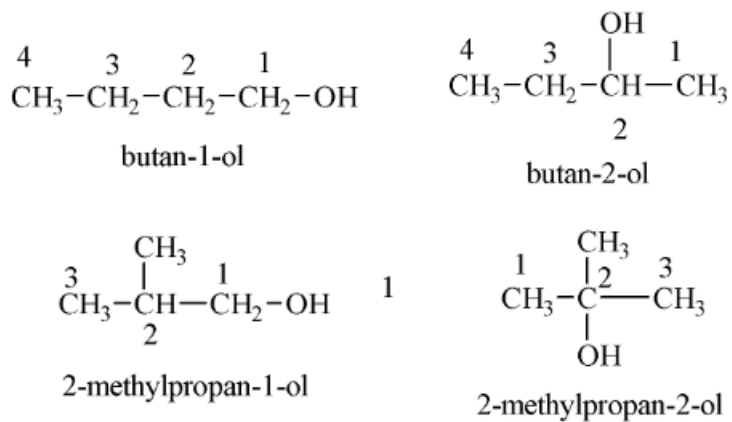
(1): As C_5H_{12} belongs to the homogeneous series C_nH_{2n+2} , i.e. alkane, we have

the following 3 structural isomers:



(2): Refer to that in (1), there is 0.

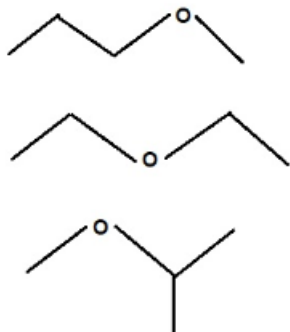
(3): As shown:



There are 4 classes.

Note: I think what “classes” MEXT refers to is “isomers”, otherwise there are only 3 classes: 1-degree, 2-degree and 3-degree alcohols.

(4): As shown:



There are 3 classes.

(5): The boiling point of substances is determined by the strength of inter-molecular force between molecules.

- 1) The intermolecular force is weak van der Waals' force.
- 2) The intermolecular force is the hydrogen bond (due to the $-\text{OH}$ group).
- 3) The intermolecular force is the weak van der Waals' force.
- 4) The intermolecular force is weak van der Waals' force with a slight effect of polarity.

Among them, 2 has the strongest intermolecular force, and hence the highest boiling point.

(6):

1) Nitrobenzene is formed, which is a substitution reaction ($-\text{NO}_2$ substituted $-\text{H}$).

2) Chlorobenzene is formed, which is a substitution reaction ($-\text{Cl}$ substituted $-\text{H}$).

3 Cyclohexane is formed, which is an addition reaction ($-\text{H}$ added to the double bond).

4 Hexachlorocyclohexane is formed, which is an addition reaction ($-\text{Cl}$ added to the double bonds).

5) Benzene sulfonic acid is formed, which is a substitution reaction ($-\text{SO}_3\text{H}$ substituted $-\text{H}$).

(7):

There are four cases:

$-\text{NH}_2$ from alanine and $-\text{COOH}$ from glycine join together.

$-NH_2$ from glycine and $-COOH$ from alanine join together.

$-NH_2$ from alanine and $-COOH$ from alanine join together.

$-NH_2$ from glycine and $-COOH$ from glycine join together.

All cases give different peptides. Therefore, there are 4 structural isomers.

(8):

Among common sugars, only sucrose (1) is not a reducing sugar.

Note: As sucrose is formed with a beta-fructose with the anomeric carbon used to form the glycosidic linkage, it cannot convert to an open chain form with aldehyde group, which gives the reducing property of sugar.

VI:

(1):

1 The aqueous solution of phenol is acidic (the H atom in the $-OH$ group can dissociate).

2 True.

3 False.

4 Phenol doesn't contain $-CHO$ group which undergoes the silver mirror reaction.

5 $FeCl_3$ can be used to test the phenol group, which turns purple as a positive result.

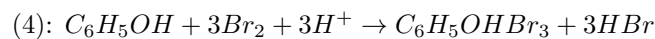
6 Phenol reacts with nitric acid to form 2,4,6-trinitrophenol, which is a common explosive.

7 The hydrogenation of phenol required Ni catalyst and high temperature.

8 Same as 4, phenol doesn't contain -CHO group to undergo the reaction.

(2): Phenol is produced by the cumene process, which uses cumene as an intermediate.

(3): Hydrogen gas forms after sodium is added into phenol.



Number of moles of demanded $C_6H_6Br_6$ yield = $\frac{298}{6 \cdot 12 + 6 + 16 + 3 \cdot 80} = \frac{149}{167} \text{ mol}$

Number of moles of raw material phenol = $\frac{94}{6 \cdot 12 + 6 + 16} = 1 \text{ mol}$.

Therefore, phenol is in excess. By considering the molar ratio, the required amount of $Br_2 = \frac{149}{167} \cdot 3 \approx \text{2.7} \text{ mol}$.

Note: In fact, the test for excess and limited is unnecessary as the atomic economy of every chemical reaction is less than or equal to 100%.

(5): Formaldehyde.

Note: Almost all productions of thermosetting resins require formaldehyde.

VII:

The dehydration of ethanol with H_2SO_4 produces ethene (12) at high temperature. Moreover, the addition of O_2 with $PdCl_2/CuCl_2$ to ethene gives ethanol (6) and the addition of H_2O with acid catalyst to ethene gives ethanol (21). The dehydration of ethanol with H_2SO_4 produce diethylether (2) when the temperature is not high enough.

Oxidising ethanol with oxidising agent $H^+/K_2Cr_2O_7$ gives ethanal (6). And the further oxidation of ethanal gives ethanoic acid (7). Calcium ethanoate is formed after ethanoic acid is neutralised by $Ca(OH)_2$ and the dry distillation of calcium ethanoate gives acetone (15).

Heat ethanol with HI forms iodoethane (22).

Esterification of ethanol with ethanoic acid gives ethyl ethanoate (23).

After the iodoform reaction of ethanol, iodoform (8) is formed.