# 2019 TJC JC2 H2 Chemistry Prelim MCQ Worked Solutions

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| **C** | **C** | **D** | **B** | **A** | **C** | **C** | **B** | **B** | **A** |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| **C** | **D** | **A** | **D** | **D** | **A** | **A** | **B** | **D** | **C** |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **B** | **D** | **B** | **A** | **C** | **B** | **D** | **B** | **A** | **C** |

**Question 1** **Answer: C**

| Particle | Neutron | Nucleon | Proton | Electron |
|---|---|---|---|---|
| U | 16 | 33 | 17 | 17 |
| $V^-$ | 18 | 35 | 17 | 18 |
| $S^{2-}$ | 16 | 32 | 16 | 18 |
| $T^{2+}$ | 17 | 34 | 17 | 15 |
| $Q^{3-}$ | 16 | 31 | 15 | 18 |

**Question 2** **Answer: C**

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$
x 0.95x
$CH_4 + 3/2\ O_2 \longrightarrow CO + 2H_2O$
0.05x

If combustion is complete, x $dm^3$ $CH_4$ will require 2x $dm^3$ $O_2$.
Combustion of 1 mol $CH_4$ to form CO, requires 3/2 mol $O_2$ ie ½ mol $O_2$ less than complete combustion.
To obtain 0.05x mol CO will need 0.05x/2 mol less $O_2$.
Amt of $O_2$ needed for incomplete combustion = 2x – 0.05x/2

Or
Volume of methane burnt = y $dm^3$
5% of methane is burnt to give CO and the remaining 95% is burnt to give $CO_2$
Vol of methane burnt to give CO = 0.05y
Vol of methane burnt to give $CO_2$ = (1-0.05)y

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
Volume used (1-0.05)y 2(1-0.05)y

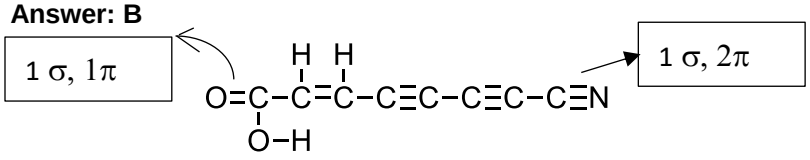
$CH_4 + 3/2O_2 \rightarrow CO + 2H_2O$
Volume used 0.05y 3/2(0.05y)

Vol of $O_2$ used = 2(1-0.05)y + 3/2(0.05y)
= 2y – 2(0.05)y + 3/2(0.05y)
= 2y – ½ (0.05y)

**Question 3** **Answer: D**

Na : $[Ne]3s^1$ (1 unpaired electron)
$P^{3-}$ : [Ar] (0 unpaired electron)
V : $[Ar]3d^34s^2$ (3 unpaired electron)
$Mn^{2+}$: $[Ar]3d^5$ (5 unpaired electron)

**Question 4** **Answer: B**



**Question 5** **Answer: A**

$ICl_2^-$ : 2BP + 3 LP, shape linear, Bond angle $180^0$, non-polar
$CO_2$ : 2 BP, shape linear, Bond angle $180^0$ , non-polar
$BCl_3$ : 3 BP shape trigonal planar, Bond angle $120^0$ , non-polar
$ClO_2^-$ : 2 BP + 2 LP, shape bent, Bond angle $<109.5^0$ , polar
HCN : 2 BP, shape linear, Bond angle $180^0$, polar
$XeF_4$ : 4 BP + 2 LP, shape square planar, Bond angle $90^0$, non-polar

**Question 6** **Answer: C**

I Both diamond and silicon have giant molecular structures. The atomic radius of C is smaller than Si. C-C bond length is shorter than Si-Si bond. Diamond has a higher mp than silicon as more energy is needed to break the stronger C-C bonds.

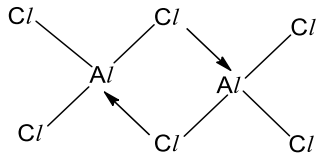
II $H_2O$ is able to form more hydrogen bonds on average compared to $NH_3$ as it has 2 lone pair of electrons on O.

III $SiCl_4$ has a simple molecular structure and $Al_2O_3$ has a giant ionic structure. The id-id attractions between $SiCl_4$ molecules is weaker than the strong ionic bonds in $Al_2O_3$.

IV Both $Br_2$ and $ICl$ have similar $M_r$. The id-id attractions between $Br_2$ molecules is weaker than the pd-pd attractions between $ICl$ molecules.

**Question 7** **Answer: C**

**1** Structure of dimer $Al_2Cl_6$




Shape of $AlCl_3$ = Trigonal planar hence bond angle is $120^o$.

Shape of $Al_2Cl_6$ = Tetrahedral about each Al atom hence bond angle is not $120^o$.

**2** Using ideal gas equation, pV = nRT
pV = (m/M) RT where M = molar mass
$(1.16 \times 10^5)(250 \times 10^{-6}) = (x / 214.9)(8.31)(500)$
**X = 1.50 g**

**3** Size of electron cloud for : $Al_2Cl_6$ > $AlCl_3$
Extent of distortion of electron cloud for: $Al_2Cl_6$ > $AlCl_3$
**Strength of intermolecular id-id : $Al_2Cl_6$ > $AlCl_3$**
Deviation from ideality for: $Al_2Cl_6$ > $AlCl_3$

**Question 8** **Answer: B**

$3C(s) + Cr_2O_3(s) \longrightarrow 2Cr(s) + 3CO(g) \quad \Delta H = +790 \text{ kJ mol}^{-1}$

$\Delta H_{rxn} = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$

$+790 = 3\,\Delta H_f(CO) - \Delta H_f(Cr_2O_3)$

$+790 = 3\,\Delta H_f(CO) - (-1120)$

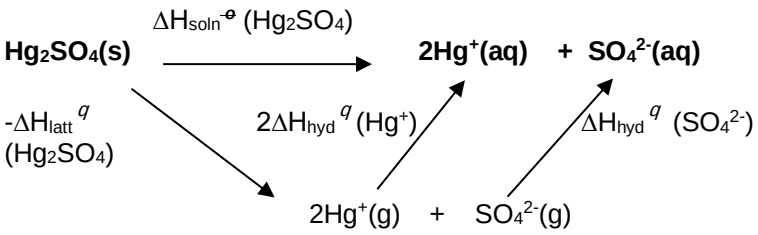
$\Delta H_f(CO) = (+790 - 1120) / 3 =$ **$-110 \text{ kJ mol}^{-1}$**

By definition, $C(s) + \frac{1}{2}O_2(g) \longrightarrow CO(g) \quad \Delta H_f(CO) = -110 \text{ kJ mol}^{-1}$

Hence, $2C(s) + O_2(g) \longrightarrow 2CO(g) \quad 2\,\Delta H_f(CO) = -220 \text{ kJ mol}^{-1}$

**Question 9** **Answer: B**

**Energy cycle for $\Delta H_{soln}{}^{q}$ $Hg_2SO_4$**




By Hess' law:

$$\Delta H_{soln}{}^{q}\ (Hg_2SO_4) = -\Delta H_{latt}{}^{q}\ (Hg_2SO_4) + 2\Delta H_{hyd}{}^{q}\ (Hg^+) + \Delta H_{hyd}{}^{q}\ (SO_4^{2-})$$
$$= -(-2127) + 2(-625) + (-1160)$$
$$= \underline{\textbf{- 283 kJ mol}^{-1}}$$

Since the calculated value of $\Delta H_{soln}{}^{q}$ $(Hg_2SO_4)$ is a negative value at r.t.p., it means that:

1. **Correct.** Magnitude is 283 kJ $mol^{-1}$
2. **Correct.** $\Delta H_{latt}{}^{q} \propto \frac{q_+ q_-}{r_+ + r_-}$, since $Hg^+$ has a bigger ionic radius as compared to $Cd^+$ ($q^+$, $q^-$, $r^-$ same), $\Delta H_{latt}{}^{q}$ of $Hg_2SO_4$ is less exothermic than that of $Cd_2SO_4$.
3. **Incorrect.** $\Delta G_{soln}{}^{\ominus}$ of $Hg_2SO_4$ is less negative than $\Delta G_{soln}{}^{\ominus}$ of $Cd_2SO_4$ since $Hg_2SO_4$ is less soluble than $Cd_2SO_4$.

**Question 10** **Answer: A**

$E^{q}_{cell} = E^{q}_{red} - E^{q}_{oxi}$

$0.3\ V = E^{\ominus}_{Cu^{2+}/Cu} - E^{\ominus}_{X^{2+}/X}$

$0.5\ V = E^{\ominus}_{Cu^{2+}/Cu}{}^{q} - E^{\ominus}_{Y^{2+}/Y}$

$0.4\ V = E^{\ominus}_{Z^{2+}/Z} - E^{\ominus}_{Cu^{2+}/Cu}{}^{q}$

From the data in the terms of increasing positive value: $E^{\ominus}_{Z^{2+}/Z} > E^{\ominus}_{Cu^{2+}/Cu} > E^{\ominus}_{X^{2+}/X} > E^{\ominus}_{Y^{2+}/Y}$
Tendency to be reduced for : $\mathbf{Z}^{2+}$, $Cu^{2+}$, $\mathbf{X}^{2+}$, $\mathbf{Y}^{2+}$
Thus, the strongest to the weakest oxidising agents is $\mathbf{Z}^{2+}$, $Cu^{2+}$, $\mathbf{X}^{2+}$, $\mathbf{Y}^{2+}$

**Question 11** **Answer: C**

$NO_3^- + 10H^+ + 8e \rightleftharpoons \mathbf{NH_4^+} + 3H_2O \qquad E^{q} = 0.87\ V$ -- (1)

$NO_3^- + 2H^+ + e \rightleftharpoons \mathbf{NO_2} + H_2O \qquad E^{q} = 0.81\ V$ --(2)

As $[H^+]$ increases. By *Le Chatelier's Principle*, the position of both equilibria shifts to the right to decrease $[H^+]$, favouring reduction

Oxidising ability of $NO_3^-$ increases while reducing abilities of $NO_2$ and $NH_4^+$ decreases.

Since for eqm (2), a lesser number of moles of $H^+$ is required for one mole of $NO_3^-$ to be reduced, there is greater tendency for equilibrium (2) to shift to the right hence backward reaction is less favoured. Hence, $NO_2$ is a weaker reducing agent where $[H^+] = 10^{-5}$ mol $dm^{-3}$ < standard condition of 1 mol $dm^{-3}$).

**Question 12** **Answer: D**

Rate would be slower as concentration of nitric acid is lower. Amount of products would be lesser as nitric acid is the limiting agent and there are less amount of nitric acid used in the 2nd scenario (0.025 mol vs 0.030 mol)

**Question 13** **Answer: A**

Total pressure increases at constant volume but *partial pressure* of individual product and reactant remains constant. So position of equilibrium will NOT shift at all.

**Question 14** **Answer: D**

$[H^+] = \sqrt{K_a C}$

When the acid is diluted, the conc of acid drops, so $[H^+]$ will drop too → pH increases, following a logarithm function since pH = -lg$[H^+]$.

However at infinitely dilute condition, $[H^+]_{overall} = [H^+]_{acid} + [H^+]_{water}$, where $[H^+]_{acid} << [H^+]_{water}$, so $[H^+]_{overall} \approx [H^+]_{water} = 10^{-7}$ mol $dm^{-3}$ at 25 °C. So the pH at infinitely dilute condition will reach a constant value of 7.

**Question 15** **Answer: D**

$Zn_3[Fe(CN)_6]_2 \rightleftharpoons 3Zn^{2+} + 2[Fe(CN)_6]^{3-}$

At eqm, there are 3y mol of $Zn^{2+}$ and 2y mol of $[Fe(CN)_6]^{3-}$.

$K_{sp} = [Zn^{2+}]^3 [Fe(CN)_6^{3-}]^2$

$= (3y)^3(2y)^2 = 108y^5 =$ **W**

$y = \sqrt[5]{\frac{\mathbf{W}}{108}}$

$[Fe(CN)_6^{3-}] = 2 \times \sqrt[5]{\frac{\mathbf{W}}{108}} = \sqrt[5]{\frac{\mathbf{8W}}{27}}$

**Question 16** **Answer: A**

$pK_a$ value of –COOH = 1.9, –SH = 8.1 and $-NH_3^+$ = 10.3.
At isoelectric point, only $–COO^-$ and $–NH_3^+$ exist, so pI = ½ (1.9+8.1) = 5.0

Hence only Bromocresol Green and Methyl Red can detect the isoelectric point of cysteine as the pI is within the working range of both indicators.

**Question 17** **Answer: A**

**X** is A*l*:

- $Al_2O_3$ has no reaction with water due to high lattice energy.
- $AlCl_3$ undergoes hydrolysis with water to give an acidic solution of pH 3
- $Al_2O_3$, an amphoteric oxide, reacts with HC*l* to form $AlCl_3$ (chloride salt) and water.

**Y** is Na

- $Na_2O$ reacts with water to forms NaOH (formation of hydroxide).
- NaC*l* undergoes only hydration with water to form a solution with pH = 7
- $Na_2O$, a basic oxide, reacts with HC*l* to form NaC*l* and $H_2O$.

**Z** is Si

- $SiO_2$ does not react with water due to its giant covalent structure
- $SiCl_4$ reacts with water to give an acidic solution pH 1
- $SiO_2$ does not react with HC*l*.

**Question 18** **Answer: B**

Thermal stability is increased by (a) lower polarising power of the cation and (b) lower polarisability of the anion.

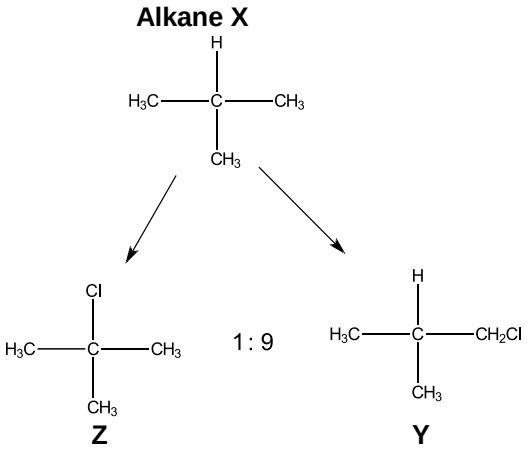
$Ba^{2+}$ has a lower polarising power than $Ca^{2+}$ due to its larger ionic radius. As $BaSO_4$ requires a higher temperature for decomposition, it is thermally more stable due to the lower polarising power of $Ba^{2+}$. It is not due to the polarisability of the $SO_4^{2-}$ anion because the $SO_4^{2-}$ anion is larger and more polarisable than $CO_3^{2-}$.

Statement 1 and 4 are incorrect as it does not help to explain thermal stability. Statement 2 is incorrect because $SO_4^{2-}$ is more easily polarised than $CO_3^{2-}$ ions.

**Question 19** **Answer: D**

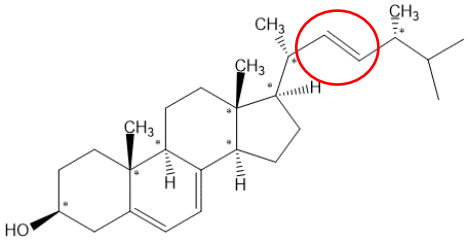
Option **A** is correct as there are 4 dative bonds formed in the complex to the central copper ion, hence coordination number is 4.
Option **B** is correct as these are ligand exchange reactions with no change in oxidation state. Copper (II) complexes are formed in this reaction scheme.
Option **C** is correct as **Q** is formed in presence of excess ammonia and the complex $[Cu(NH_3)_4(H_2O)_2]^{2+}$ is formed.
Option **D** is incorrect as reduction reaction does not occur during a ligand exchange reaction (Reaction III).

**Question 20** **Answer: C**

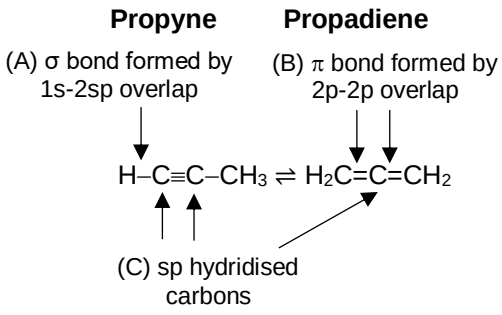



**Question 21** **Answer: B**

**Max number of stereoisomers = $2^{8+1} = 2^9$ [Note: C=C in ring does not exhibit cis-trans isomerism]**




**Question 22** **Answer: D**




D is incorrect as the C-C single bond in propyne is sp-$sp^3$ overlap, while that in propane ($CH_3$–$CH_2$–$CH_3$) is $sp^3$-$sp^3$ overlap. The bond length in propyne is shorter as sp orbital has more s character, resulting in more effective overlap.

**Question 23** **Answer: B**

A is incorrect as oxidation of methylbenzene to benzoic acid requires $KMnO_4/H_2SO_4$, heat.
C is incorrect as aqueous NaOH needs to be added to liberate the free phenylamine and concentrated $HNO_3$ will result in substitution at 2, 4 position.
D is incorrect as $LiAlH_4$ will reduce carboxylic acid back to primary alcohol.

**Question 24** **Answer: A**

Option 1 is incorrect as stereoisomers have different biological properties.
Option 2 is correct. Molecular formula = $C_{12}H_{18}Br_6$, Empirical formula = $C_2H_3Br$
Option 3 is incorrect as the carbon atoms are tetrahedral.

**Question 25** **Answer: C**

A 1 mole of compound **G** reacts with Na (alcohol, phenol, carboxylic acid) to produce 1.5 mole of $H_2$.
B Tertiary alcohol cannot be oxidised so no green solution obtained.
C 1 mole of compound **G** reacts with 2 moles of NaOH (carboxylic acid and phenol) so product has a charge of 2-.
D 1 mole of compound **G** reacts with 3 moles of $CH_3COCl$ (alcohol, phenol, amine) to produce 3 moles of HCl.

**Question 26** **Answer: B**

**1** $CH_2=CHCO_2H$ gives $CH_2=CHCH_2OH$ (gains 2 H and loses 1 O). Alkene is not reduced.
→ net change in $M_r$ = +2 - 16 = -14

**2** $CH_3CH_2COCO_2H$ gives $CH_3CH_2CH(OH)CH_2OH$ (gains 4H and lose 1 O)
→ net change in $M_r$ = +4 - 16 = -12

**3** $CH_3CH_2CONH_2$ gives $CH_3CH_2CH_2NH_2$ (gains 2H and lose 1 O)
→ net change in $M_r$ = +2 -16 = -14

**Question 27** **Answer: D**

A Product is $CH_3CH_2CH_2CHCN(OD)$
B Product is $CH_3CH_2CH_2CO_2D$
C Product is $CH_3CH_2CH_2CO_2D$ and $^+ND_2(CH_3)_2$
D Product is $CH_3CH_2CH_2CO_2^-$ which does not contain deuterium.

**Question 28** **Answer: B**

Increasing $pK_b$: arrange from most basic to least basic.
1 and 2 are both secondary amines. However, 1 has an electron-withdrawing group (C=O) attached to it which reduces the electron density on the nitrogen and hence it is less basic than 2.
3 is neutral.
4 is less basic than 1 and 2 since the lone pair of electrons on the nitrogen is delocalised into the benzene ring and hence less available for dative bonding with a proton.

**Question 29** **Answer: A**

ala-met
met-gly-ala
gly-ala-gly
gly-ser
ser-lys

Therefore, the structure of the polypeptide is ala-met-gly-ala-gly-ser-lys

**Question 30** **Answer: C**

Working backwards via pattern recognition: “break C=C bond and place back O at C=C bond” to get first carbonyl compound and the remaining fragment belongs to the second carbonyl compound.

A & D: forms from 2 molecules of butanone

B: forms from 1 molecule of butanone and 2 molecules of ethanal

C: C=C on the right is NOT at C2 and C3 from C=O group