2018 Year 5 Promotion Examinations Section A Suggested Solutions

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	B	D	B	D	B	D	A	C	C	A	C	D	B	A	C

Q1(B)

Oxidation half-equation	$6OH^- + S \longrightarrow SO_3^{2-} + 3H_2O + 4e^-$
Reduction half-equation	$4e^- + 2S \longrightarrow 2S^{2-}$
Overall equation	$6OH^- + \underline{3}S \longrightarrow \underline{2}S^{2-} + \underline{1}SO_3^{2-} + 3H_2O$

Q2(D)

Balanced equation:

$C_xH_yS_z(g) + (x + z + {}^y/_4)O_2(g) \longrightarrow xCO_2(g) + zSO_2(g) + {}^y/_2H_2O(l)$

After cooling to room temperature, the gases which remain are CO_2, SO_2 and unreacted O_2 i.e.

$$V_{CO_2} + V_{SO_2} + V_{unreacted\ O_2} = 90cm^3$$

The acidic gases, CO_2 and SO_2, react with the aqueous alkali. Therefore, $V_{unreacted\ O_2} = 70cm^3$.

$$V_{O_2\ reacted} = 100 - 70 = 30cm^3$$
$$V_{CO_2} + V_{SO_2} + 70 = 90 \Rightarrow V_{CO_2} + V_{SO_2} = 20cm^3$$

	$C_xH_yS_z(g) + (x+z+{}^y/_4)O_2(g) \longrightarrow xCO_2(g) + zSO_2(g) + {}^y/_2H_2O(l)$			
V / cm^3	10	30	20	--
mole ratio	1	3	2	--

$x+z+{}^y/_4 = 3$ and $x + z = 2 \Rightarrow$ **y = 4**

x = z = 1. Therefore, compound is CH_4S.

Q3(B)

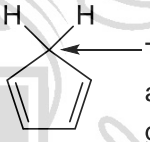
A	Incorrect. Using data from *Data Booklet*, radius of Ni^{2+} = 0.069nm and radius of Fe^{2+} = 0.061nm.
B	Correct. Using data from *Data Booklet*, 1st IE of Ni = 736 kJ mol^{-1} and 1st IE of Fe = 762 kJ mol^{-1}.
C	Incorrect. Number of electrons in Fe^{2+} = 24. Number of electrons in Ni atom = 28. They do not have the same no. of electrons i.e. they are not isoelectronic.
D	Incorrect. Angle of deflection $\propto \frac{q}{m}$ $\frac{q}{m}(Ni^{2+}) = \frac{2}{58.7} = 0.0341$ $\frac{q}{m}(Fe^{2+}) = \frac{2}{55.8} = 0.0358$ Fe^{2+} will be deflected more than Ni^{2+}.

Q4(D)

From question, presence of unpaired e^- ⇒ paramagnetic.

A	Electronic configuration of Cl^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. 2 unpaired electrons in 3p subshell ⇒ Cl^+ is paramagnetic.
B	Electronic configuration of V^{3+} : [Ar] $3d^2$. 2 unpaired electrons in 3d subshell ⇒ V^{3+} is paramagnetic.
C	Electronic configuration of O^- : $1s^2\ 2s^2\ 2p^5$. 1 unpaired electron in 2p subshell ⇒ O^- is paramagnetic.
D	Electronic configuration of Cu^+ : [Ar] $3d^{10}$. No unpaired electrons in Cu^+ ⇒ Cu^+ is not paramagnetic.

Q5(B)

1	**Incorrect**.  This C is sp^3 hybridised and has a tetrahedral geometry. Hence, the molecule is not planar.
2	**Correct**. From question: "…form the **planar** cyclopentadienyl anion…". In order for the anion to be planar, every carbon atom in the anion is sp^2 hybridised.
3	**Incorrect.** Due to the resonance stabilisation in the anion, the pi electron density is evenly distributed over the entire anion. Hence, the carbon-carbon bond lengths in the anion are equal.

Q6(D)

The line is represented by an equation of the form y = mx where m is the gradient.

If pV is the y-axis and T is the x-axis, the ideal gas equation can be manipulated to fit the form y = mx.

$$\underbrace{pV}_{y} = \overbrace{(nR)}^{m}\underbrace{T}_{x}$$

Q7(A)

Refer to the definitions in Energetics I lecture notes to help you remember whether a process is endothermic or exothermic. It is also helpful to consider from a Chemical Bonding perspective whether some processes are endothermic or exothermic.

A	Enthalpy change of atomisation is always positive.
B	Enthalpy change of combustion is always negative.
C	Enthalpy change of formation can be positive or negative, depending on the reaction.
D	Enthalpy change of solution can be positive or negative, depending on the reaction.

Q8(C)

$\Delta G = \Delta H - T\Delta S$

For a reaction to be spontaneous *at all temperatures*, $\Delta H < 0$ (narrow down options to **B** and **C**) and $\Delta S > 0$. The reaction in **C** involves the production of gaseous products which are significantly more disordered than the liquid reactants i.e. $\Delta S > 0$ for reaction in **C**.

Q9(C)

D	**Incorrect**. At a given time, the gradient of the graph gives the rate of reaction. The initial rate for the reaction at T_1 is greater than that for the reaction at T_2. Hence, **T_1 is greater than T_2**.
A	**Incorrect**. At the higher temperature (T_1), more H_2 is formed i.e. more products are formed. When the temperature is increased from T_2 to T_1, the system favours the endothermic reaction which, in this case, is forward reaction which produces more H_2. Hence the forward reaction is endothermic.
B	**Incorrect**. The addition of solid carbon does not alter the concentrations of any species and does not affect the position of equilibrium.
C	**Correct.** From **B**, increasing the temperature from T_2 to T_1 causes the position of equilibrium to shift right, consuming more reactants to form more products. Hence K_c increases with increasing temperature.

Q10(A)

The two peaks in the reaction profile diagram indicate that the given reaction, **A** + 2**B** ⟶ 2**C**, proceeds via a two-step mechanism. The reactions involved in the two steps are:

Step 1 : **A** + 2**B** ⟶ **AB** + **B**
Step 2 : **AB** + **B** ⟶ **2C**

1	**Correct.** Since the activation energy for step 2 is greater than that of step 1 (deduced from the reaction profile diagram), step 2 is the slow step. From step 2 (the slow step), rate = k[**AB**][**B**] = k[**A**][**B**]^2. The reaction is 2nd order with respect to **B**.
2	**Correct.** Since step 2 is the rate determining step and involves the reaction between 1 molecule of **AB** and 1 molecule of **B**, the rate determining step involves a bimolecular reaction i.e. involving two molecules.
3	**Incorrect**. Since **A** and **B** are both consumed but not regenerated, **A** and **B** are reactants and not catalysts. There are no catalysts in this reaction.

Q11(C)

	^{238}**U** ⟶ **Pb**	Molar ratio
Initial amt / mol	1 : 0	-
Amt after 1 half-life / mol	½ : ½	1 : 1
Amt after 2 half-lives / mol	¼ : ¾	1 : 3

Time taken = $2(4.5 \times 10^9) = 9.0 \times 10^9$ years.

Q12(D)

When $[X]_{eqm} < [Y]_{eqm}$, the position of equilibrium lies to the right ⇒ $\Delta G^{\ominus} < 0$ i.e. at points **3** and **4**.

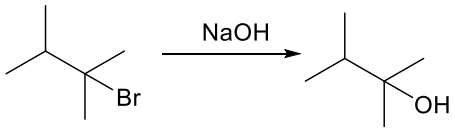
Q13(B)

Equal amounts of reactants with total initial pressure p were reacted. Therefore, initial partial pressure of PCl_3 = initial partial pressure of Cl_2 = ½ p. Eqm partial pressure of PCl_5 is given to be $^1/_5$ p.

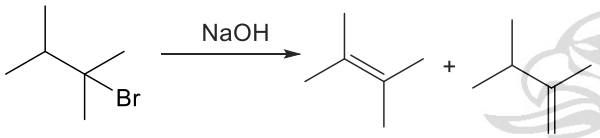
	PCl_3(g) +	Cl_2(g) ⇌	PCl_5(g)
Initial P	½ p	½ p	0
Change in P	$-^1/_5$ p	$-^1/_5$ p	$+^1/_5$ p
Eqm p	$^3/_{10}$ p	$^3/_{10}$ p	$^1/_5$ p

$$K_c = \frac{\frac{1}{5}p}{\left(\frac{3}{10}p\right)\left(\frac{3}{10}p\right)} = \frac{20}{9p}$$

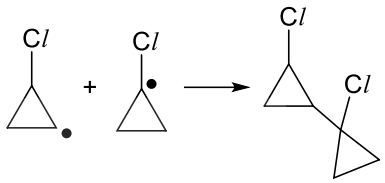
Q14(A)



Substitution : Br in the reactant is substituted with OH.

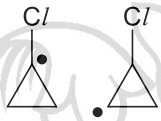


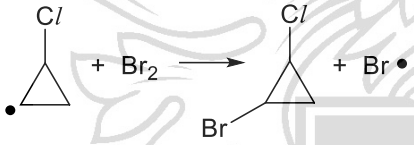
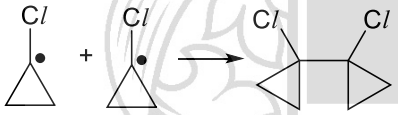
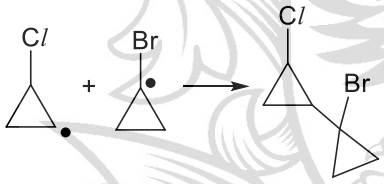
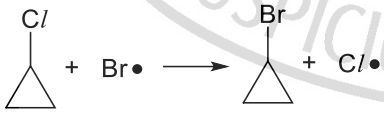
Elimination : Elimination of HBr from the reactant to result in a C=C in the product.

D	**Possible.** This product can be formed from 

Q15(C)

When bromine is reacted with chlorocyclopropane in a free radical substitution reaction, two different radicals of chlorocyclopropane can be formed:



A	**Possible.** This product can be formed from 
B	**Possible.** This product can be formed from 
C	**Not possible.** This product can only be formed from the following reaction:  The bromocyclopropyl radical comes from bromocycloproane, which is formed from the following reaction.  ΔH_r = BE(C–Cl) – BE(C–Br) = 340 – 280 = +60 kJ mol^{-1} $\Delta S_r \approx 0$ kJ mol^{-1} K^{-1} Therefore, ΔG_r = +60 kJ mol^{-1} > 0 i.e. the formation of bromocyclopropane from chlorocyclopropane is not spontaneous.