HWA CHONG INSTITUTION
2017 C1 H2 CHEMISTRY PROMOTIONAL EXAM
SUGGESTED SOLUTIONS

Paper 1

1	2	3	4	5	6	7	8	9	10
C	B	B	A	C	B	D	D	B	C
11	12	13	14	15	16	17	18	19	20
D	A	D	A	C	C	A	A	B	D

Comments

1 **C** The relative charges of one proton and one neutron are +1 and 0 respectively. Hence, the net charge of the combination of quarks which make up one proton should add up to +1. Similarly, the net charge of the combination of quarks which make up one neutron should add up to 0.

	proton (relative charge = +1)	neutron (relative charge = 0)
A	one up and one down net charge = $1\left(+\frac{2}{3}\right)+\left(-\frac{1}{3}\right)=+\frac{1}{3}$	one up and two down net charge = $1\left(+\frac{2}{3}\right)+2\left(-\frac{1}{3}\right)=0$
B	one up and two down net charge = $1\left(+\frac{2}{3}\right)+2\left(-\frac{1}{3}\right)=0$	two up and one down net charge = $2\left(+\frac{2}{3}\right)+1\left(-\frac{1}{3}\right)=+1$
C	two up and one down net charge = $2\left(+\frac{2}{3}\right)+1\left(-\frac{1}{3}\right)=+1$	one up and two down net charge = $1\left(+\frac{2}{3}\right)+2\left(-\frac{1}{3}\right)=0$
D	two up and one down net charge = $2\left(+\frac{2}{3}\right)+1\left(-\frac{1}{3}\right)=+1$	two up and one down net charge = $2\left(+\frac{2}{3}\right)+1\left(-\frac{1}{3}\right)=+1$

2 **B** A radioactive atom X undergoes alpha decay (i.e. emits a helium nucleus) to form Y.

$$X \rightarrow Y + {}^{4}_{2}He^{2+}$$

Considering the conservation of mass, the nucleon number (or mass number) of Y must be (4 units) lower than that of X.

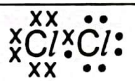
Another identical radioactive atom X undergoes beta decay (i.e. emits an electron) to form Z.

$$X \rightarrow Z + {}^{0}_{-1}e^{-}$$

∴ Since the atomic number of Z and that of the electron must sum up to the atomic number of X, the atomic number of Z must be (1 unit) greater than that of X.

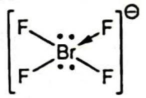
FYI (not in syllabus): In a beta decay, 1 neutron is split into 1 proton and 1 electron.

3 **B** Based on the definition given in the question, a substance is termed paramagnetic when it contains at least one unpaired electron.

A	Electronic configuration of Al: $1s^2\ 2s^2\ 2p^6\ 3s^2 \boxed{3p^1}$ 1 unpaired electron
B	Cl_2:  no unpaired electron ⇒ paramagnetic
C	Electronic configuration of Mn: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 \boxed{3d^5} 4s^2$ 5 unpaired electrons
D	Electronic configuration of Ti: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 \boxed{3d^2} 4s^2$ 2 unpaired electrons

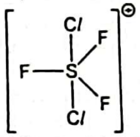
4 **A** Based on the given context, it can be implied that a molecule without trigonal bipyramidal geometry cannot undergo Berry psuedorotation mechanism.

1 BrF_4^- (4 bond pairs and 2 lone pairs around central atom Br):



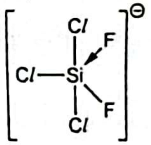
square planar around Br

2 $SF_3Cl_2^+$ (5 bond pairs and 0 lone pair around central atom S):



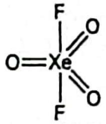
trigonal bipyramidal around S

3 $SiF_2Cl_3^-$ (5 bond pairs and 0 lone pair around central atom Si):



trigonal bipyramidal around Si

4 XeO_3F_2 (5 bond pairs and 0 lone pair around central atom Xe):



trigonal bipyramidal around Xe

∴Only 1 does not have trigonal bipyramidal geometry and cannot undergo Berry pseudorotation (Option A).

5 C

	$2NO(g)$	+	$O_2(g)$	→	$2NO_2(g)$
initial amount / mol	0.0944 (excess)		0.0378 (limiting)		0
change / mol	−2(0.0378)		−1(0.0378)		+2(−0.0378)
final amount / mol	0.0188		0		0.0756

Total n(gases) = 0.0188 + 0.0756 = 0.0944 mol

Final $p = \frac{nRT}{V} = \frac{(0.0944)(8.31)(71+273)}{(250+500)\times 10^{-6}} = 360\ 000$ Pa = 360 kPa

6 B Given that the density of a gas is defined as the mass of 1 dm^3 of the gas,
⇒ density of gas mixture α average M_r of gas mixture

	planet	major gases / % by number of molecules
A	Jupiter	H_2 89.8, He 10.2 average M_r of gas = $\frac{(89.8)(2)+(10.2)(4)}{100} = 2.20$
B	Saturn	H_2 96.3, He 3.25, CH_4 0.45 'ge M_r of gas = $\frac{(96.3)(2)+(3.25)(4)+(0.45)(16)}{100} = 2.13$
C	Uranus	H_2 82.5, He 15.2, CH_4 2.3 average M_r of gas = $\frac{(82.5)(2)+(15.2)(4)+(2.3)(16)}{100} = 2.63$
D	Neptune	H_2 80.0, He 19.0, CH_4 1.0 average M_r of gas = $\frac{(80.0)(2)+(19.0)(4)+(1.0)(16)}{100} = 2.52$

∴ The atmosphere on Saturn has the lowest density.

7 D Option 1 is incorrect. Counter examples include $Mg(s) + O_2(g) \rightarrow MgO(s)$ or $CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g)$, where entropy change is negative.

Option 2 is incorrect. Counter example: $CO_2(g) \rightarrow CO_2(aq)$, dissolution of a gas results in negative ΔS.
The enthalpy change of solution is defined for any solute, not just solids. In the above scenario, the entropy change is negative.
Furthermore, refer to your Physical Chemistry lecture notes for situations where the dissolution of an ionic solid can result in negative entropy change, i.e. when restriction of the movement of water molecules is more significant.

Option 3 is correct. The process of vaporisation always results in a change from liquid state to a gaseous state, resulting in an increase in entropy.

8 D Students need to use the equation $\Delta G = \Delta H - T\Delta S$. From the equation, there is a decrease in the amount of gas particles during the reaction, so the ΔS should be negative and the ΔH is given as a negative value. A reaction or process is spontaneous when ΔG is negative. In order for ΔG to be negative, temperature needs to be low for $|T\Delta S| < |\Delta H|$. At too high a temperature, ΔG becomes positive and the reaction becomes non-spontaneous.

9 B From the units of the rate constant, it can be deduced that the reaction is overall first order. Hence, half-life of the reaction can be found by $t_{½} = \frac{\ln 2}{6.93} = 0.1$ min
$12.5 = (100) \times (0.5)^{\text{no. of half-lives}}$
no. of half-lives = 3

Since it will take three half-lives for concentration to decrease from 100% to 12.5%, the time taken will be 3 × 0.1 min = 0.3 min.

10 C First, you will need to find the order with respect to each reactant and write the rate equation.

Using the inspection method
By comparing experiments 1 and 2, $[ClO_2]$ remains constant while $[OH^-]$ increases 2 times, causing the initial rate to increase 2 times. Initial rate is directly proportional to $[OH^-]$ and hence, reaction is first order with respect to OH^-.

By comparing experiments 2 and 3, $[ClO_2]$ increases 2 times while $[OH^-]$ decreases 4 times, causing the initial rate to remain the same for both experiments. Since reaction was found to be first order with respect to OH^-, initial rate will decrease 4 times if $[ClO_2]$ was kept the same. Hence, the doubling of $[ClO_2]$ resulted in the initial rate to increase 4 times. Since initial rate is directly proportional to $[ClO_2]^2$, reaction is second order with respect to ClO_2.

Therefore, the rate equation is written as rate = $k[ClO_2]^2[OH^-]$

1	ClO_2 undergoes disproportionation as it was oxidised to ClO_3^- and reduced to ClO_2^- simultaneously.
2	Substituting data from experiment 1 into the rate equation, $5.75 \times 10^{-3} = k\,(0.050)^2(0.020)$ $k = 115\ mol^{-2}\ dm^6\ s^{-1}$
3	The rate equation is written as rate = $k[ClO_2]^2[OH^-]$

11 D

	K_c & Units
A	$K_c = \frac{[COF_2]^2}{[CF_4][CO_2]}$ unitless
B	$K_c = \frac{[H_2]^4}{[H_2O]^4}$ unitless
C	$K_c = \frac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][CH_3CH_2OH]}$ unitless
D	$K_c = \frac{[CH_3CO_2H][CH_3NH_2]}{[CH_3CONHCH_3]}$ mol dm^{-3} Note: H_2O should not appear in the K_c as it is the solvent in this case

12 A According to the shape of the graph, an increase in temperature results in a decrease in the fraction of *X*, a product, in the equilibrium mixture. An increase in temperature will favour the endothermic process. Hence, it can be deduced that the formation of *X* is exothermic. By comparing the two curves, an increase in pressure results in a decrease in the fraction of *X* in the equilibrium mixture. Hence, it can deduced that *X* is present on the side of the equation with greater number of moles of gaseous molecules.

13 D

1	Increasing pressure has no effect on the value of equilibrium constant.
2	Adding an iron catalyst has no effect on the yield.
3	Iron catalyst provides an alternative pathway with lower activation energy for both forward and backward reactions. Hence, rate constant of both forward and backward reactions increases.

14 A Two molecules came together to form a bigger molecule with the elimination of a small molecule of water. Hence, this is a condensation reaction.

15 C Option **A** incorrect. H_2 is not a product of a free-radical substitution reaction anyway.

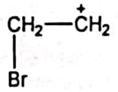
Option **B** incorrect. HBr is obtained during the propagation reactions, not during any of the termination reactions.

Option **C** is the best choice.
The termination reaction is $\bullet CH_2Cl + \bullet CHBrCl \rightarrow CH_2ClCHBrCl$
$\bullet CH_2Cl$ and $\bullet CHBrCl$ could be produced in the earlier propagation reactions:
$CH_3Cl + Br\bullet \rightarrow \bullet CH_2Cl + HBr$
$\bullet CH_2Cl + Br_2 \rightarrow CH_2BrCl + Br\bullet$
$CH_2BrCl + Br\bullet \rightarrow \bullet CHBrCl + HBr$

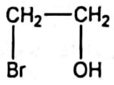
Option **D** is a much less likely answer than **C**.
The termination reaction would be $\bullet CHCl_2 + \bullet CHBrCl \rightarrow CHCl_2CHBrCl$
$\bullet CHCl_2$ would have to be obtained in an earlier propagation reaction. However, there is no Cl_2 molecule or $Cl\bullet$ radical to react with CH_3Cl.

16 C Incomplete combustion of a hydrocarbon fuel produces CO. Answer is **C**.
N_2 is already present in the air (in the vehicle engine), it is not produced by combustion anyway.
$N_2 + O_2 \rightarrow 2NO$, this occurs under the high temperature in the engine. However, this reaction doesn't involve a hydrocarbon fuel.
Complete combustion of a hydrocarbon fuel produces CO_2.

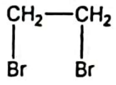
17 A This is an electrophilic addition reaction.
Mechanism step 1 produces a carbocation intermediate and a Br^- ion.


$\underset{Br}{CH_2}-\overset{+}{C}H_2$

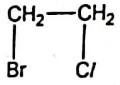
carbocation intermediate


$\underset{Br}{CH_2}-\underset{OH}{CH_2}$

possible product 1


$\underset{Br}{CH_2}-\underset{Br}{CH_2}$

possible product 2

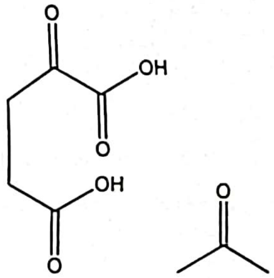

$\underset{Br}{CH_2}-\underset{Cl}{CH_2}$

possible product 3

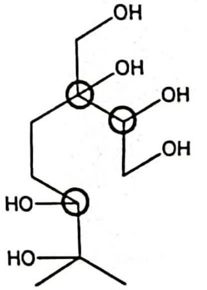
The carbocation intermediate could react with H_2O, or Br^-, or Cl^- to give products 1, 2, 3 respectively.

18 A Statement 1 is correct. Alkene C=C reacts with Br_2 or Cl_2 (halogens), and would react with BrCl (inter-halogen compound) in a similar manner.

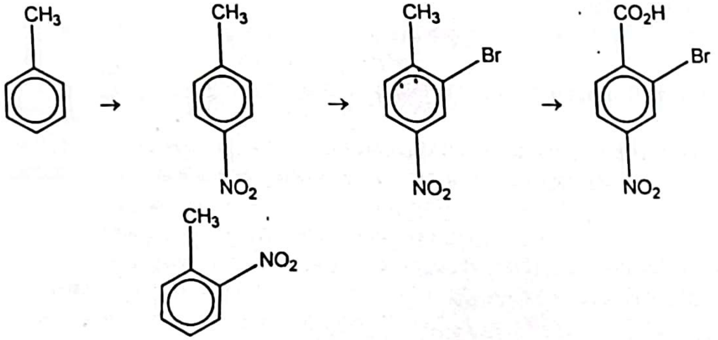
Statement 2 is correct. The oxidative cleavage organic products are:



Statement 3 is correct. The mild oxidation product is shown below with the chiral centres circled.



9 **B** This question is about the orientating effect of groups in electrophilic substitution reactions. Use *Data Booklet* Section 8 to find the best sequence that gives the fewest number of products other than the desired one (i.e. best yield of desired product). Sequence **B** is the best choice.



20 **D** Statement 1 is incorrect. Benzene is a covalent molecule, there are no ions, it does not conduct electricity. The delocalised π cloud of electrons only occur on each benzene ring, these electrons do not delocalise over to any neighbouring benzene molecules. Ethene does not contain delocalised electrons. Ethene does not conduct electricity.

Statement 2 is incorrect. In benzene (C_6H_6), all six carbon-carbon bonds are intermediate in length between that of a C–C single bond (e.g. in ethane), and that of a C=C double bond (e.g. in ethene).

Statement 3 is correct. Benzene undergoes electrophilic substitution while ethene undergoes electrophilic addition (not the other way round in Statement 4).