ANDERSON SERANGOON JUNIOR COLLEGE

H2 Chemistry 9729 **2019 JC2 Prelim Exam Paper 1 Worked Solutions**

1 Answer: **C**

^{68}Ge has 32 protons and 36 neutrons.
When 'a proton changes into a neutron', ^{68}X contains 31 protons and **37 neutrons**.
X is gallium (Ga) which is in Group 13, i.e. has 3 valence electrons, only 1 of which is in the outer p orbitals.
Ga: [Ar] $3d^{10}$ $4s^2$ $4p^1$

2 Answer: **C**

X: The biggest jump in IE is between 4th to 5th electron hence, X has 4 valence electrons and belongs to Group 14.
Y: The biggest jump in IE is between 6th to 7th electron hence, X has 6 valence electrons and belongs to Group 16.

Possible covalent compounds formed are CO_2, CS_2 and SiO_2.

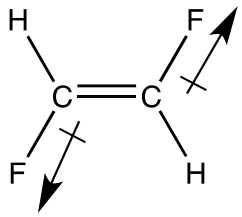
3 Answer: **C**

Notice that N^1 and N^3 only have two covalent bonds with carbon atoms. To fulfil octet, they need to gain one electron each from the central Mg atom to form N^-. Hence, N^1 and N^3 are involved in ionic bonding.

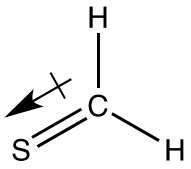
N^2 and N^4 have three covalent bonds with carbon atoms. They have one lone pair each, which interacts with the central Mg^{2+} ion via co–ordinate bonding.

4 Answer: **D**

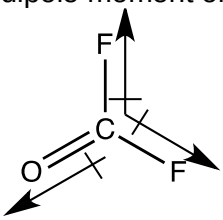
Dipole moments cancel out.



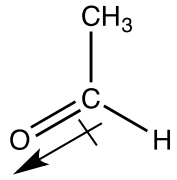
B: Dipole moment is smaller than that in D since S is less electronegative than O.



C: Dipole moment is smaller than that in D as the net dipole moment of C–F bonds reduces the dipole moment of C=O bond



D:



5 Answer: **C**

$$pV = nRT$$

$$pV = \frac{m}{M}RT$$

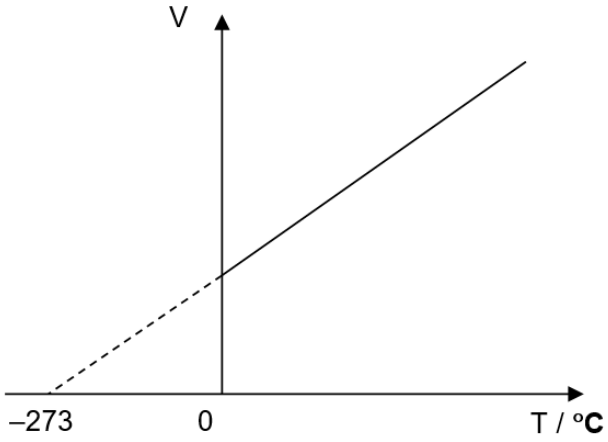
$$pM = \frac{m}{V}RT$$

$$pM = \rho RT$$

p is directly proportional to ρ. The graph should be a straight line that passes through the origin. Hence, A is wrong

*p*V = nRT
p is directly proportional to T / K. The graph should be a straight line that passes through the origin. Hence, B is wrong.

V is also directly proportional to T / K.



Hence, C is correct

*p*V = nRT
$\frac{1}{p} = \frac{V}{nRT} : \frac{1}{p}$ α V at constant *T*. The graph should be a straight line that passes through the origin. Hence, D is wrong.

6 Answer: **B**

The solution is one which is able to maintain the pH at about 5, hence it is an acidic buffer.
Only the mixture in option B can form an acidic buffer.

7 Answer: **C**

$H_2O \rightleftharpoons H^+ + OH^-$
$K_w = [H^+][OH^-]$

Since the stoichiometric coefficients of H^+ and OH^- ions are equal in the above equation, $[H^+] = [OH^-]$ at all temperatures. Hence, water is a neutral liquid at all temperatures. Option B is wrong.

When temperature of water increases, K_w also increases. This shows that the position of equilibrium has shifted to the right, i.e. the forward reaction is favoured, and more H^+ and OH^- ions are produced. Since the endothermic reaction is favoured when temperature increases, the dissociation of water (forward reaction) is an endothermic reaction. Option D is wrong.

The value of K_w does not provide any information about hydrogen bonding between water molecules. Option A is wrong.

8 Answer: **C**

A: Volatility of halogens (X_2) <u>decreases</u>: $F_2 > Cl_2 > Br_2 > I_2$
X_2 has simple molecular structure with weak id–id forces of attraction between molecules. Down the group, the number of electrons increases hence the electron cloud is bigger and more easily polarised resulting in stronger id–id forces of attraction. Thus, the boiling point increases down the group and the halogens become less volatile.

B: Bond energy of X–X bond <u>decreases</u> down group 17

molecule	bond energy of X–X (kJ mol^{-1})
F_2	+ 158
Cl_2	+ 244
Br_2	+ 193
I_2	+ 151

C: Down group 17, $E^{\ominus}_{(X2/X^-)}$ becomes less positive.
$\Rightarrow$ <u>increasing</u> tendency for X^- to be oxidised to X_2

D: Thermal stability of hydrogen halides <u>decreases</u> down group 17 as the bond energy of H–X bond decreases down the group.

molecules	bond energy of H–X (kJ mol^{-1})
H–F	562
H–Cl	431
H–Br	366
H–I	299

9 Answer: **A**
There are 3 chlorine atoms in 1 molecule of trichloroisocyanuric acid.

No. of moles of trichloroisocyanuric acid in the pool = $\frac{2.50 \times 10^6 \times 1.50 \times 10^{-3}}{232.5} = 16.1$

No. of moles of chlorine atoms = 3 x 16.1 = 48.38
No. of chlorine atoms = 48.38 x 6.02 x 10^{23} = **<u>2.91×10^{25}</u>**

10 Answer: **B**

No. of moles of H_2S = $\frac{720}{24000} = 0.03\,\text{mol}$

No. of moles of HNO_3 = $\frac{40}{1000} \text{ x } 0.500 = 0.02\,\text{mol}$

Mole ratio of H_2S: HNO_3 = 3 : 2
From the given half–equation,
1 mole of H_2S loses 2 moles of electrons → 3 moles of H_2S will lose 6 moles of electrons
2 moles of HNO_3 gain 6 moles of electrons → **1 mole of HNO_3 will gain 3 moles of electrons**

original oxidation state of N in HNO_3:
(+1) + x + 3(–2) = 0
x = +5
Since the nitrogen atom in HNO_3 gains 3 electrons,
+5 – 3 = +2

new oxidation state of N = **+2** (N in NO has an oxidation state of +2)

11 Answer: **D**

Q' (heat taken in by water) = 300 x 4.2 x T J

Q (heat evolved by the reaction) = $\frac{m}{46.0} \times 1371 \times 1000$ J

% efficiency = $\frac{300 \times 4.2 \times T}{\frac{m}{46.0} \times 1371 \times 1000} \times 100\% = \frac{300 \times 4.2 \times T \times 46.0}{m \times 1371 \times 1000} \times 100\%$

12 Answer: **A**

To calculate enthalpy change of formation of $MgCO_3$(s), use the following:

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

The enthalpy of combustion of C(s) is the same as the enthalpy change of formation of CO_2(g). Hence, option A is correct.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

13 Answer: **A**

When a liquid boils, energy is needed to overcome the forces of attraction between liquid particles, hence ΔH is positive (i.e. endothermic).

When a liquid boils, the state changes from liquid to gaseous state, which is more disordered, hence ΔS is positive.

14 Answer: **B**

rate = $k[(CH_3)_3CCl]$ (first order reaction)

When $[(CH_3)_3CCl]$ is **doubled**, the **rate** is **doubled**.
Given that 20% of 0.02 mol dm^{-3} $(CH_3)_3CCl$ has reacted in 5 min, 0.004 mol dm^{-3} has reacted.
Hence, for 0.04 mol dm^{-3} $(CH_3)_3CCl$, 0.008 mol dm^{-3} would have reacted as rate has doubled.
% reacted = (0.008/0.04) x 100% = **20%**

15 Answer: **B**

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expt no.	initial $[O_2]$ / mol dm^{-3}	initial [NO] / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
1	2.0	1.0	8.0
2	1.0	1.0	*s*
3	1.0	*t*	16.0
4	0.5	0.5	*u*

Given: rate = $k[O_2][NO]^2$

Comparing expt 1 & 2, in which initial [NO] is constant,
When $[O_2]$ is halved, rate will be halved $\Rightarrow$ *s* = 8.0/2 = **4.0**

Comparing expt 2 & 3, in which initial $[O_2]$ is constant,
Since rate increases 4 times (from 4.0 to 16.0) and order of reaction w.r.t. NO is 2, [NO] must have doubled (from 1.0 to 2.0) $\Rightarrow$ *t* = **2.0**

Alternatively,

$$(\frac{1.0}{1.0})(\frac{t}{1.0})^2 = (\frac{16.0}{4.0})$$

$$t = 2.0$$

Comparing expt 3 & 4,

$$(\frac{0.5}{1.0})(\frac{0.5}{2.0})^2 = (\frac{u}{16.0})$$

$$u = 0.5$$

16 Answer: **D**

1: The rate equation can be derived as follows:
Based on the slow step (rds): rate = $k\,[OH^+]\,[I^-]^2\,[H^+]$ ———— (1)

For the first step (fast step), $K_c = \dfrac{[OH^+]}{[H_2O_2][H^+]}$

$$[OH^+] = K_c\,[H_2O_2]\,[H^+] \quad \text{———— (2)}$$

Substituting (2) into (1): rate = $k\,K_c\,[H_2O_2]\,[H^+]\,[I^-]^2\,[H^+]$

rate = $k_1\,[H_2O_2]\,[H^+]^2\,[I^-]^2$

which is not consistent with the experimentally obtained rate equation.

2: The overall chemical equation obtained by summing up the 2 equations in the slow and fast steps is different from that given in the option.

$NO_2 + NO_2 \rightarrow \cancel{N_2O_3} + O$ (slow)
$\underline{\cancel{N_2O_3} + CO \rightarrow CO_2 + 2NO}$ (fast)
$CO + 2NO_2 \rightarrow CO_2 + 2NO + O$

(given) $CO + NO_2 \rightarrow CO_2 + NO$

3: Based on the slow step (rds), the rate equation should be: **rate = k_3 $[H_2]$** which is not consistent with the experimentally obtained rate equation.

17 Answer: **C**

$\Delta G^{\ominus} < 0$ at points 1, 2 and 3.

When K_c is more than 1, it implies that the position of equilibrium lies more towards the right. This means that the forward reaction is spontaneous. Therefore, consider points where $\Delta G^{\ominus} < 0$.

18 Answer: **C**

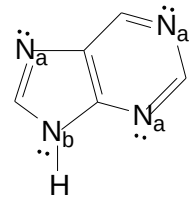
At t_1: When NO_2 was removed, the position of equilibrium shifts right to produce more NO_2, causing the amount and hence pressure of NO_2Cl to decrease.
At t_2: when the temperature was increased, the position of equilibrium shifts left to favour the endothermic reaction by absorbing more heat. This causes the pressure of NO_2Cl to increase.

At t_3: when more NO_2Cl was added, it led to a sharp increase in pressure. The position of equilibrium then shifts right to counter act the change, leading to a decrease in the pressure of NO_2Cl.

19 Answer: **D**

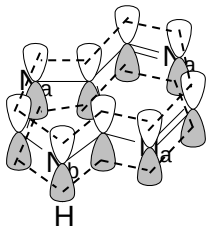
1. Gas produced suggests H_2 gas. $H_2 + Fe^{2+} \rightarrow Fe + 2H^+$ is <u>not spontaneous</u> as $E^{\ominus}_{cell} = -0.44\ V < 0$
2. $[Fe(H_2O)_6]^{2+} + 2OH^- \rightleftharpoons Fe(OH)_2 + 6H_2O$
   This is an <u>acid–base reaction</u> since the OH^- accepts the H^+ from the water ligand to form H_2O.
3. $Fe^{2+}(aq)$ ion has a low charge density and hence can only hydrolyse in water to a small extent. It can only undergo a simple precipitation reaction with Na_2CO_3 to form $FeCO_3(s)$.

20 Answer: **A**

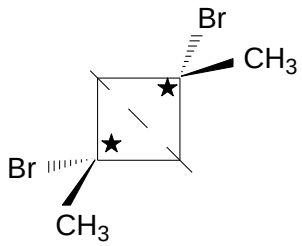


All the carbon atoms and nitrogen atoms labelled as N_a are sp^2 hydridised (3 electron regions).

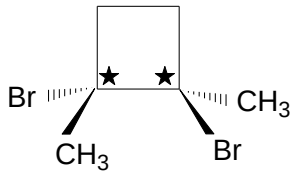
Although there are 4 electron regions around the nitrogen atom labelled as N_b, N_b is also sp^2 hybridised. This is because given that N_b is non–basic, its lone pair of electrons resides in the unhybridised p orbital and can be delocalised due to the overlapping of the p orbitals. Hence, the lone pair of electrons on N_b is not available to accept a H^+.



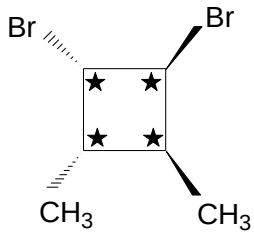
21 Answer: **C**

Option 1: 

has a plane of symmetry

Option 2: 

has no plane of symmetry, thus is optically active

Option 3: 

has no plane of symmetry, thus is optically active

22 Answer: **D**

The correct reagents should be:
Option 1: NaOH in ethanol
Option 2: NaCN in ethanol
Option 3: no reaction due to partial double bond character in the C–C*l* bond

23 Answer: **C**

$-NO_2$ and $-COCH_3$ groups are 3–directing, which explains why option A is wrong.
Option B is wrong as C–F bond is too strong for nucleophilic substitution to take place.
Option D is wrong as free–radical substitution (FRS) at a sp^2 hybridised C does not occur readily / FRS cannot be easily controlled (i.e. a mixture of products is obtained)

24 Answer: **A**

$NaBH_4$ can reduced ketone to 2^o alcohol but it not able to reduce carboxylic acid, alkenes or nitrobenzene

25 Answer: **D**

Since there is no reaction with Fehling's solution, **Z** is not an aliphatic aldehyde. Hence, option **B** is wrong.

1 mole of **Z** reacts with 2 moles of Na metal, hence there are two groups that can react (carboxylic acid, phenol or alcohol)

When PCl_5(s) is added to **Z,** it reacts with carboxylic acid in option **D** to from acyl chloride, which further reacts with the phenol group to form a sweet smelling ester.

26 Answer: **B**

Q hydrolyses readily in water to produce a strongly acidic solution of CH_3CO_2H and **HCl**. Hence, the resulting solution formed has the lowest pH.

P, **R** and **S** are weak acids which ionise partially in water.
The presence of electronegative atoms (Cl and Br) on **R** and **S** exerts an electron–withdrawing effect on $ClCH_2CH_2COO^-$ and $BrCH_2CH_2COO^-$ respectively, which disperses the negative charge and stabilises the anion.
Since Cl is more electronegative than Br, it exerts a stronger electron–withdrawing effect on $ClCH_2CH_2COO^-$ and hence stabilises the anion more. $ClCH_2CH_2COOH$ is more acidic than $BrCH_2CH_2CO_2H$. Hence, the resulting solution from **R** has a lower pH than **S**.

CH_3CH_2COOH contains an electron–donating alkyl group, which intensifies the negative charge of the anion. Thus, dissociation of CH_3CH_2COOH to give H^+ ions is least favourable. The resulting solution from **P** has the highest pH.

27 Answer: **D**

1: The empirical formula is $C_7H_{15}ON$. When the compound in option 1 is hydrolysed, it gives CH_3CO_2H, which has the empirical formula CH_2O.

2: The empirical formula is $C_8H_{17}ON$. When the compound in option 2 is hydrolysed, it gives $CH_3CH_2CH_2CO_2H$, which has the empirical formula C_2H_4O.

3: The empirical formula is $C_7H_{15}ON$. When the compound in option 3 is hydrolysed, it gives $(CH_3)_2CHCO_2H$, which has the empirical formula C_2H_4O.

28 Answer: **C**

1. The α–amino group should have a pK_a value of 9.0 because it is closer to the –COOH group which is electron–withdrawing in nature.
2. Equal amounts of $H_3N^+CH(CO_2H)(CH_2)_4NH_3^+$ and $H_3N^+CH(CO_2^-)(CH_2)_4NH_3^+$ are present at point **A**.
3. At point **C**, $H_2NCH(CO_2^-)(CH_2)_4NH_3^+$ is present, which is a zwitterion with no net charge.
4. At point **B**, $H_3N^+CH(CO_2^-)(CH_2)_4NH_3^+$ is present which has a net positive charge, hence will migrate to cathode(–).

29 Answer: **A**

1. When calculating the oxidation state (O.S), consider the bonds around the atom of concern.
   C bonded to O in quinone has 3 bonds: C=O and two C–C. Since O.S of O in C=O is –2, C is +2.
   Similarly, C bonded to O in quinol has 3 bonds: C–O and two C–C. O.S of O in C–O is –1, hence O.S of C is +1.

2. $E^{\ominus}_{cell}$ = +1.52 – (+0.70) = +0.82 V > 0

3. $E^{\ominus}_{cell}$ = +0.70 – (+0.17) = +0.53 V > 0 (reaction is spontaneous)

30 Answer: **A**

Q = current x time = n_eF
current α n_e since time and F are a constant

Electrolysis of aqueous sulfuric acid at the anode:
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Electrolysis of molten aluminium oxide at the cathode:
$Al^{3+} + 3e^- \rightarrow Al$

$$\frac{n_{O_2}}{n_{Al}} = \frac{0.01}{0.01}$$

$$\frac{n_{\text{electrons transferred for } O_2}}{n_{\text{electrons transferred for } Al}} = \frac{4}{3} = \frac{\text{current used in electrolysis 1}}{\text{current used in electrolysis 2}}$$

$$\frac{4}{3} = \frac{I}{\text{current used in electrolysis 2}}$$

$\Rightarrow$ current used in electrolysis 2 = $\frac{3}{4}I$.