

HWA CHONG INSTITUTION 2020 C2 H2 CHEMISTRY PRELIMINARY EXAMINATION SUGGESTED SOLUTIONS

Paper 1

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	40.000	1.27	3.2 NB	2	1000	100		1.100	1.00
1	2	3	4	5	6	7	8	9	10
D	В	С	В	D	С	В	С	В	D
11	12	13	14	15	16	17	18	19	20
Α	В	Α	D	Α	В	D	С	Α	D
21	22	23	24	25	26	27	28	29	30
С	С	С	Α	Α	D	В	Α	В	С

D This question tests the writing of electronic configurations.

The electronic configuration and the number of unpaired p electrons for each of the species are shown below.

A	Al ²⁻ : 1s ² 2s ² 2p ⁶ 3s ² 3p ³ (3 unpaired p electrons) O ⁺ : 1s ² 2s ² 2p ³ (3 unpaired p electrons)
В	N: 1s ² 2s ² 2p ³ (3 unpaired p electrons) Cl ²⁺ : 1s ² 2s ² 2p ⁶ 3s ² 3p ³ (3 unpaired p electrons)
С	C: $1s^2 2s^2 2p^2$ (2 unpaired p electrons) C l^+ : $1s^2 2s^2 2p^6 3s^2 3p^4$ (2 unpaired p electrons)
D	B ⁻ : 1s ² 2s ² 2p ² (2 unpaired p electrons) S ⁺ : 1s ² 2s ² 2p ⁶ 3s ² 3p ³ (3 unpaired p electrons)

2 B A simple molecular solid should have a low melting point (due to weak intermolecular forces) and does not conduct electricity (due to lack of mobile charge carriers – ions or free electrons). It may be soluble or insoluble in water depending on the type of intermolecular forces that it can form with water.

Since the unknown compound is a solid at room temperature, the answer cannot be A due to the melting point.

C A A σ bond involves head-on overlap of the orbitals of two bonded atoms, thus electron density is highest between the two atoms e.g.
 p atomic orbital
 p atomic orbital
 p atomic orbital
 sigma-bonding molecular orbital

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B This is a correct statement. An example of such a compound would be MgCO₃ where ionic bonds exist between Mg²⁺ and CO₃²⁻ while covalent bonds exists within CO₃²⁻.
 C A triple bond consists of two π bonds and one σ bond instead.
 C is incorrect.
 D This is a correct statement. This is also part of the reasoning how cis-trans isomerism arises in alkenes.

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В

This question tests your understanding of ideal gas and involves the use of the ideal gas equation PV = nRT.

Α	PV = nRT $PV = (mass/M_r)RT$				
1	Since density = mass / V,				
VÅ	$P \times M_r$ = density $\times R \times T$ density = $P \times M_r/(RT)$				
SIT	Thus, the density of an ideal gas at constant temperature is <i>directly</i> proportional to the pressure.				
В	PV = nRT V = 1 mol × RT / P				
vA	At the same T and P, 1 mol of any ideal gas has the same volume V. This statement is correct.				
С	As seen from the ideal gas equation, V is directly proportional temperature (in Kelvins), for a given mass (or mol) of the ideal gas constant P.				
2	However, when temperature is increased from 25 °C (298K) to 50 °C (323K), temperature is not doubled. Thus V is not doubled.				
D	Since the volume of container does not change, the partial pressure of the ideal gas should not change as well.				
S T	We may also think in terms of: Adding that second gas increases total pressure. However, the mole fraction of the first gas decreases by the same factor, hence its partial pressure does not change.				
	A B C				

D According to the question, all the carbon atoms in the organic compound are converted into CO₂ when burnt completely in excess O₂, and the nitrogen atoms are converted into N₂.

Assuming that the formula of the organic compound is $C_xH_yN_z$, then for every one mole of $C_xH_yN_z$, x moles of CO_2 will be produced and z/2 moles of N_2 will be produced.

The volume ratio of organic compound : CO_2 : N_2 = 10 cm³ : 30 cm³ : 5 cm³ = 1 : 3 : 0.5

Hence x = 3 and z = 1 which fit the molecular formula of D.

Some general guidelines for solving this kind of oxidation states / electron transfer / mole concept problem:

- Work from the reactant whose conversion is given (XeF₂ → Xe in this question)
- Use the relationship, change in oxidation state for an atom

= no. of moles of electrons transferred for 1 mol of that atom

• Link the no. of moles of a reactant reacted to the no. of moles of electrons transferred

 XeF_2 is converted to Xe, so oxidation state of Xe decreases from +2 to 0. XeF_2 is reduced, there is a gain of electrons during reduction. Oxidation state of Xe decreases by 2 units, therefore 2 mol of electrons gained for 1 mol of XeF_2 .

+2 0 XeF₂ + 2e⁻ \rightarrow Xe

 $n(XeF_2)$ reduced = 15.20/1000 × 25.0/169 = 0.00225 mol $n(e^-)$ transferred = 0.00225 × 2 = 0.00450 mol

 $n(M^{2+})$ oxidised = 10.0/1000 × 0.150 = 0.00150 mol $n(e^{-})$ transferred for 1 mol of M^{2+} = 0.00450 ÷ 0.00150 = 3 Therefore, oxidation state of M increases by 3 units, from +2 to +5 \Rightarrow Ans. C

7 B From the melting point trend, it can be deduced that these third period elements are A*l*, Si, P and S.

Property X corresponds to the first ionisation energies of these elements. First ionisation energies generally increase across the period due to increasing effective nuclear charge. However, the first ionisation energy of S is lower than that of P due to the interelectronic repulsion experienced by the electrons in the same p orbital. Students may also check the first IE data from the *Data Booklet*.

Property Y fits well with atomic radii data. Atomic radius decreases across the period due to increasing effective nuclear charge. The outermost electrons are held closer to the nucleus. Students may also check the atomic radii data from the *Data Booklet*.

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C From the information given, it can be deduced that X is Mg as MgO is commonly used as a refractory lining material due to its high melting point.

Y is Ca. When $CaCO_3$ is heated, it forms CaO (Z), which gives $Ca(OH)_2$ when hydrated. $Ca(OH)_2$ can be used in agriculture to treat acidic soils.

辛	Α	Ca is more reactive than Mg. As atomic radii increase, the metal atoms lose their electrons more readily (1st and 2nd ionisation energies decrease) going down the group, so they form M ²⁺ cations more easily.
LI V	В	Reducing power of the group 2 metals increases (tendency to be oxidised increases) down the group.
	С	Mg(NO ₃) ₂ decomposes at a lower temperature than Ca(NO ₃) ₂ . Apply the same reasoning like comparing MgCO ₃ vs. CaCO ₃ .
辛 HV		Mg^{2+} has smaller radius than Ca^{2+} . Mg^{2+} has higher charge density and polarising power. Mg^{2+} polarises and distorts the NO_3^- electron cloud more, the N–O bond is weakened more and would need less heating to break (the N–O bond). Hence, $Mg(NO_3)_2$ decomposes at a lower temperature than $Ca(NO_3)_2$.
希下	D	L.E. $\alpha \frac{q_+ \times q}{r_+ + r}$ Mg ²⁺ has smaller radius (r ₊) than Ca ²⁺ . Therefore, the numerical value of the L.E. of MgO is larger than that of CaO.

9 B At is below I in Group 17.

1	As the size of the atoms increases down the Group, the bond length increases and the halogen molecule dissociates more easily due to the decreasing bond strength. As such, it is expected that At_2 dissociates more easily than Cl_2 .
2	Down the group, as atomic radius increases, the bond length of the H–X bond increases and thus bond strength decreases. Hence, less energy is needed to break the H–X bond. Thus, the thermal stability of the hydrogen halides decreases down the group and H–At is expected to be less stable to heat than H–I.
3	Check the <i>Data Booklet</i> QA Notes. AgC <i>l</i> is soluble in aq. NH ₃ , AgBr is partially soluble in aq. NH ₃ , AgI is insoluble in aq. NH ₃ . Based on this trend, AgAt is most likely insoluble in aq. NH ₃ .
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Increasing volume means there is more space for the particles to move D around. There should be more ways to distribute the particles. Hence entropy should increase. В The increase in temperature increases the range of kinetic energies (widens the Boltzman distribution). There is a wider range of energies that can be distributed through the motion of the particles, thus increasing entropy. When an inert gas is added to a system at constant pressure and С constant temperature, the volume of the container will increase given the increase in the total number of moles of gas. Similar to Option A, the entropy will increase. D Removing chlorine at constant pressure and constant temperature will result in a smaller volume. This will lead to a decrease in entropy.

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10

A This question involves enthalpy change of neutralisation.

For the first two mixtures, 0.025 moles of water are formed while for the next two mixtures, 0.05 moles of water are formed.

The enthalpy change of neutralisation between NaOH and HC*l* is more exothermic as compared to the enthalpy change of neutralisation between NaOH and ethanoic acid. This is because ethanoic acid is a weak acid which partially dissociates in water. Heat is needed for the ionisation of the weak acid. We would then expect w > x and y > z.

 $\Delta H_{neut} = -q / no.$ of moles of water formed

 $q = mc\Delta T$

Hence, $\Delta T = (-\Delta H_{neut} \times no. of moles of water formed) / mc$

w should be equal to y. Although for y, it involves the production of double the no. of moles of water, the total mass (m) of the solutions doubles as well.

Similarly, x = z.





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12 B Assume a simple first order reaction, $A \rightarrow$ product

Rate = k[A]





The relationship between [A] and t is an exponential decay, given by Option B.

A Statement 1 is incorrect as for the same sample of reaction molecules, the concentration of the reactants is a constant. Hence an increase in rate will necessarily imply an increase in rate constant. (The rate constant *k* increases when a catalyst is added, or when the temperature is increased.)

Statement 2 is what you had learnt from Kinetics. Given the same condition (including temperature!), the statistical distribution of particles is the area under the Maxwell-Boltzmann distribution curve. An alternative (catalytic) pathway with a lower activation energy will imply that the proportion of reacting molecules with kinetic energy above the (new) lower activation energy is greater than that with the 'original' activation energy. This leads to an increase in the frequency of effective collision and hence an increased in reaction rate.

Statement 3 is incorrect as the addition of a catalyst will not broaden the Maxwell Boltzmann distribution curve. Broadening of the curve is a result of an increased in temperature, not addition of catalyst.

D From the graph, the yield of X increases with increasing pressure and with decreasing temperature. That means that in the course of the reaction, the amount of gaseous products is less than the amount of gaseous reactant (can be viewed as when pressure increases, position of equilibrium shifts right) and the forward reaction is exothermic (can be viewed as an increase in temperature favours the backward endothermic reaction).

Hence statements 1 and 2 are correct statements inferred from the graph.

Since the industrial conditions is provided in the graph, it could be inferred that in the industry, they are not using the highest possible pressure (think of cost of building and maintaining the reactors!) and the lowest possible temperature (think of rate of reaction!).

15 A Given that the forward reaction is endothermic, it is expected that K_w is larger at 70 °C as compared to 25 °C. Since $pK_w = pH + pOH$ and pH = pOH for neutrality, a larger K_w leads to a smaller pK_w which will result in pH (and pOH) taking a value below 7.

Options **C** and **D** are common misconceptions. The position of equilibrium is different at a different temperature, but the new $[H^+]$ and the new $[OH^-]$ remain equal.

16 B Since bromophenol blue changes colour from yellow to blue over a pH range of 3.0 to 4.6, this implies that the colour of the solution will be yellow and blue for pH < 3.0 and pH > 4.6 respectively. This eliminates option A straightaway. (We need to interpret that HIn molecule is yellow while In⁻ ion is blue.)

Option **B** is a correct option as the colour change of an indicator usually occurs within ± 1 from its p K_a and 3.8 fits a value for its p K_a .

Water has a pH of 7, so the indicator would show blue colour, which means $[In^{-}] > [HIn]$. Hence option **C** is incorrect.

The end point of the titration between a strong base and weak acid lies above pH 7 and this is way beyond the working range of bromophenol blue.

D When NH₃(aq) is added, NH₃ molecules will ionise according to the following equilibrium:

Cu(OH)₂ will be precipitated according to the following equation: (2) Cu²⁺(aq) + 2OH⁻(aq) \longrightarrow Cu(OH)₂(s) Therefore, the amount of Cu²⁺(aq) will decrease and the amount of Cu(OH)₂(s) will increase. The portion of the graph, **RQ**, would refer to Cu²⁺(aq). **PS** would

refer to precipitation of $Cu(OH)_2(s)$. Beyond point **Q**, further addition of $NH_3(aq)$ will not result in more $Cu(OH)_2$ precipitate (all Cu^{2+} already precipitated). Instead, formation of the [$Cu(NH_3)_4$]²⁺

complex occurs (blue ppt soluble in excess aq. NH_3 according to the *Data Booklet* QA Notes). More NH_3 added means more complex formed, so **QT** would refer to complex formation. The formation of the complex also results in the dissolution of Cu(OH)₂(s) which would be represented by **SU**.

18 C Using oxidation numbers

(1)

(2)

 $\begin{array}{ccc} 0 & +4 & +2 \\ Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l) \\ we would know that Pb is oxidised while PbO_2 is reduced. \\ Statement 2 is correct. \end{array}$

When Pb is oxidised, electrons are released. Electrons are needed for PbO_2 to be reduced. Hence electrons should flow from Pb to PbO_2 . Statement 1 is incorrect.

 $\ll Pb^{2+} + 2H_2O$

 $E^{\ominus} = +1.47$ V

E[⊕] = −0.13 V

Pick the half-equations and E^{\ominus} data from the *Data Booklet*. The only two choices are:

 $\ll Pb$

 $PbO_2 + 4H^+ + 2e^-$

Pb²⁺ + 2e⁻

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$E^{\ominus}_{\text{cell}} = +1.60 \text{ V}$

Could the (actual) cell e.m.f. be higher than +1.60 V?

The given overall equation shows precipitation of PbSO₄ which means a decrease in [Pb²⁺]. Therefore, the position of equilibrium (1) would shift to the right, so reduction potential PbO₂/Pb²⁺ would be more positive than +1.47 V. In addition, equilibrium (2) would shift to the left, so reduction potential Pb²⁺/Pb would be more negative than -0.13 V. Yes, the (actual) cell e.m.f. would be higher than +1.60 V. Statement 3 is correct.

The question states that this is a battery, which would be a galvanic cell system. In a galvanic cell, a spontaneous redox reaction ($E^{\oplus}_{cell} > 0$) is used to generate electricity. Statement 4 is incorrect.

A 'non-spontaneous redox reaction driven by electricity' would be electrolysis, for example, the one in Question 19.

- **19 A** Electrolysis calculations usually involves the use of
 - Q = It
 - Q = No. of moles of electrons passed × F
 - a half-equation that shows how that product of interest is obtained, plus consideration of the mole ratio linking that product of interest vs. electrons passed

 $Q = 8 \times 100 \times 60 = 48000 \text{ C}$ n(e⁻) passed = 48000 ÷ 96500 = 0.497 mol

Cathode (reduction) : $2H^+ + 2e^- \rightarrow H_2$ n(H₂) liberated = $0.497 \times \frac{1}{2} = 0.249$ mol Volume of H₂ = $0.249 \times 22.7 = 5.6$ dm³ (s.t.p.) \Rightarrow Answer A

20 D A redrawn neocarzinostatin is given below. The sphere represents sp² hybridised carbon (16 in total) and the asterisk represents chiral centres (10 in total).









C It is imperative to approach this question in a systematic manner. First, we will need to draw out the basic unbranched and branched C5 alkenes which exhibit cis-trans isomerism:

unbra	nched	branched			
	\sim				

After that, replace the H at every C atom systematically and sieve out all those which exhibit cis-trans isomerism.



22 C Option **A** is one of the propagation steps for the chain reaction between bromine and <u>methane</u> and so it's irrelevant to this question.

Option **B** is not a typical propagation step; it is not likely to occur as it is more endothermic than $Br \bullet + CH_3CH_3 \rightarrow CH_3CH_2 \bullet + HBr$ and hence less likely to occur. Moreover, the methyl radical generated is less stable than the ethyl

radical expected and hence Option **B** is likely to have a higher activation barrier.

Option **C** is similar to a typical propagation step (similar to $CH_3CH_2\bullet + Br_2 \rightarrow CH_3CH_2Br + Br\bullet$) except that it occurs with $CH_3CH_Br\bullet$ instead of $CH_3CH_2\bullet$.

Similar to Option **B**, Option **D** is not an energetically favourable propagation step. H• radicals are not produced during free-radical substitution anyway.

C Numbering the C atoms always help in keeping track the key bonds being formed and broken. From the numbering of C of the reactant and product, it can be seen that a key σ bond is formed between C1 and C6. This could only be postulated from a tertiary carbocation generated by the electrophilic addition occurring at one of the C=C.



24 A This question tests the students' understanding on the electronic effect of the lone pair of electrons on a sp² hybridised N next to the phenyl ring. Since the given information shows that under the same reaction condition, phenylamine results in tribromination and *N*-phenylacetamide results in mono-bromination, we can infer that the extent of delocalisation of the lone pair of electrons into the phenyl ring is lesser for the latter.

This could be explained by the presence of a C=O in *N*-phenylacetamide which is likely to withdraw quite a bit of electron densities away from N, making the lone pair less available for delocalisation into the phenyl ring.

A Row 1 is not likely to be the answer as none of the halogenoarene will result in the formation of precipitate with ethanolic silver nitrate.

Row 2 is not likely to be the answer as all three will form precipitate with ethanolic silver nitrate. The question wrote that the test-tube containing W does not product precipitate and hence it is likely to contain a sp^2C –Br bond which is given in row 3 (and row 1 but it's already eliminated earlier on). C–I bond is weaker than C–Br and hence we would expect precipitation to occur more quickly for Y than X.

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26 D One ulosonic acid molecule contains 5 alcohol groups and 1 carboxylic acid group.

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ROH + Na \rightarrow RO<sup>-</sup> Na<sup>+</sup> + \frac{1}{2}H<sub>2</sub>
RCO<sub>2</sub>H + Na \rightarrow RCO<sub>2</sub><sup>-</sup> Na<sup>+</sup> + \frac{1}{2}H<sub>2</sub>
1 mol ulosonic acid would react with excess Na metal to give
5\times\frac{1}{2} + 1\times\frac{1}{2} = 3 mol of H<sub>2</sub>
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The acid-base neutralisation of RCO₂H with NaOH does not give H₂.

B From the data given, since the pK_a of phenol in water is lower than that in methanol, this implies that phenol is a stronger acid in water than in methanol.

This also implies that conjugate base of phenol is more stable in water than in methanol (this has to be true since a stronger acid necessarily implies that the position of equilibrium for the dissociation of that acid in that solvent lies more to the right).

28 A Options C and D are definitely out as they are ester and amide and do not contain the methyl ketone (–COCH₃) group (must be ketones or aldehydes only) or the –CH(OH)CH₃ group.

Option **A** is actually one of the intermediates in the iodoform test. A simplified illustration of the iodoform reaction is given below.



Option **B** contains a $-CH_2OH$ next to the C=O but it will not give a positive iodoform test as the OH can't be easily replaced by iodine. Between **A** and **B**, choose **A**.

29 B The compound has 1 alcohol group (secondary alcohol) and 2 carboxylic acid groups.

Statement 1 is incorrect. We would need to convert the carboxylic acid to acyl chloride first.

Statement 2 is correct. The reaction would involve the alcohol group.



Statement 3 is correct. The alcohol group reacts with HBr (and converts to bromoalkane).



Statement 4 is incorrect. Only carboxylic acids react with NaHCO₃. 1 mol of malic acid should react with 1 mol of NaHCO₃.

30 С Compound Q has an amide group or amide linkage -CON-An amide linkage can only be made from an acyl chloride and an amine (in the laboratory). Option **C** is correct.

 $CH_3(CH_2)_9 - C - C/ + H - N \rightarrow CH_3(CH_2)_9 - C$ HC1





























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