TJC 2022 H2 Chemistry Paper 1 Answer Key

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

1 Answer: **D**

Worked Solution:

Number of neutrons in $^{31}P^{3-}$ = 31 – 15 = 16

Number of neutrons in $^{32}S^{2-}$ = 32 – 16 = 16

Thus, $^{31}P^{3-}$ are $^{32}S^{2-}$ are isotonic.

Angle of deflection of species in electric field $\propto \frac{charge}{mass}$

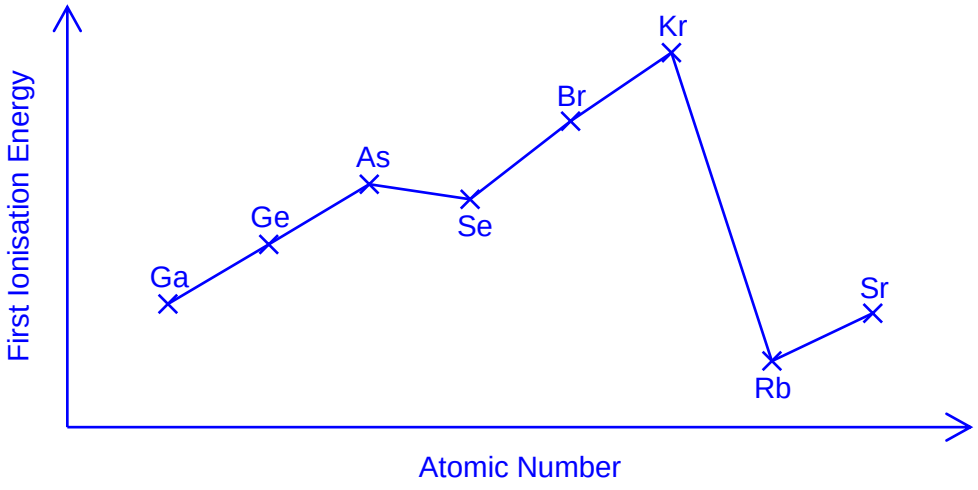
$^{31}P^{3-}$ has a higher charge and a smaller mass than $^{32}S^{2-}$. The angle of deflection of $^{31}P^{3-}$ will be greater than that for $^{32}S^{2-}$.

2 Answer: **C**

Worked Solution: 3rd electron of B comes from an inner shell, B has 3 valence electron and is from Group 13. C is from Group 15.

3 Answer: **A**

Worked Solution:



1: correct, from diagram, IE of Ga < Ge < As

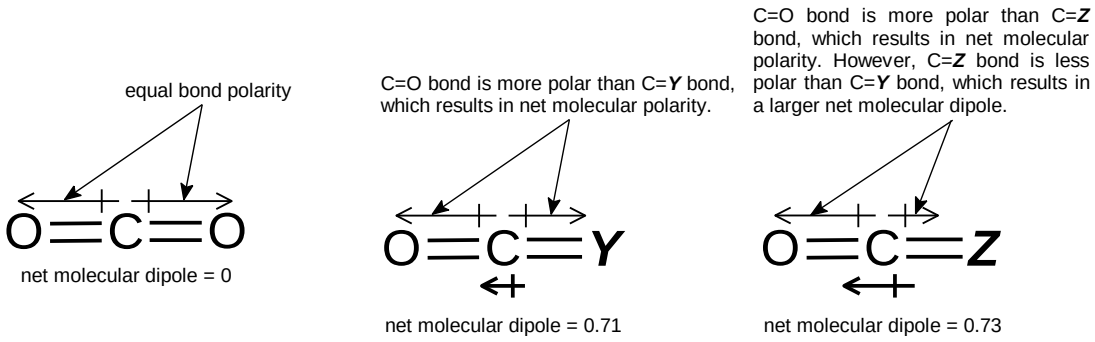
2: wrong, Se < As < Br

3: correct, Se < Br < Kr

4: wrong, Sb < As < P

4 Answer: **B**

Worked Solution:



×	**A**	O is the most electronegative element in Group 16. Thus, the C=O bond is the most polar amongst the three bonds.
✓	**B**	O is the most electronegative element in Group 16. Since C=***Z*** bond is less polar than C=***Y*** bond, this suggests that ***Y*** is more electronegative than ***Z***. *(See diagrams above*.)
×	**C**	While this statement is true, it does not explain the observed trend.
×	**D**	Bond length has little bearing on net molecular dipole.

5 Answer: **D**

Worked Solution:

SO_2 has bent shape, bond angle < 120°. SO_3 has trigonal planar shape, bond angle is 120°.

6 Answer: **B**

Worked Solution: PV= nRT

A. Incorrect. The number of moles of L is greater than number of moles of M

B. Correct. At constant T, PV= n x constant

C. Incorrect. At constant T, V = nRT/P, straight line pass through origin, different gradient for L & M

D. Incorrect. At constant P, V = (nR)/p x T = constant x T

7 Answer: **B**

Worked Solution:

element		pH of solution when oxide of element is added to water	pH of solution when chloride of element is added to water
X	Na	$Na_2O + H_2O \rightarrow 2NaOH$ pH = 13	NaCl(aq), pH = 7
Y	P	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ pH = 2	$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ pH = 2
Z	Al	Al_2O_3 is insoluble in water pH = 7	$AlCl_3$ undergoes hydration and hydrolysis. pH of solution is about 3.

8 Answer: **C**

Worked Solution: Ionic radii of group 2 cations increases down the group. Charge density and polarising power decrease down the group, thermal stability increases down the group.

9 Answer: **A**

A. Incorrect statement - Chlorine has a greater reducing strength than bromine. Bromine will not be able to displace chloride.

B. AgCl is insoluble in nitric acid.

C. Chlorine oxidises thiosulfate to sulfate, which forms white ppt of barium sulfate.

D. Chlorine displaces iodide, brown iodine solution is formed.

10 Answer: **A**

Worked Solution:

Let V_{CH_4} cm^3 be the volume of CH_4 in mixture.

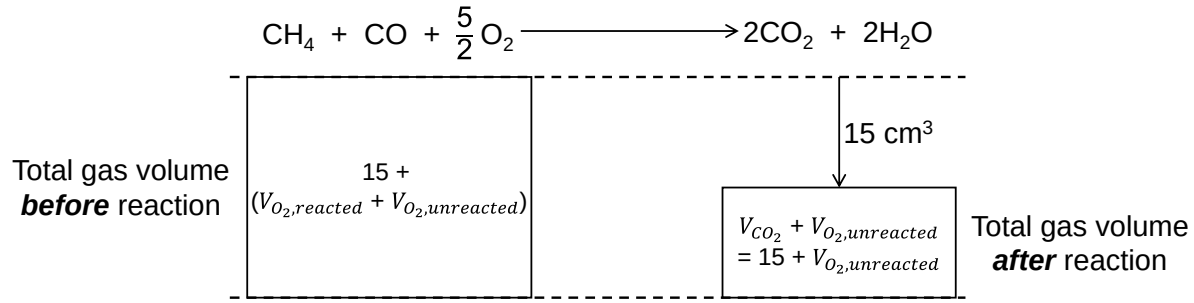
$\Rightarrow$ Volume of CO in mixture = (15 – V_{CH_4}) cm^3

	CH_4	:	O_2	:	CO_2
mole ratio	1	:	2	:	1
volume ratio	V_{CH_4}	:	$2\,V_{CH_4}$		V_{CH_4}

	CO	:	O_2	:	CO_2
mole ratio	1	:	$\frac{1}{2}$	:	1
volume ratio	$15 - V_{CH_4}$	:	$\frac{1}{2}(15 - V_{CH_4})$	:	$15 - V_{CH_4}$

Since total volume of CH_4 and CO combusted = 15 cm^3, and equimolar ratios of CH_4 to CO_2, and of CO to CO_2 are formed, total volume of CO_2 formed = 15 cm^3

Total volume of O_2 added into reaction vessel = ($V_{O_2,reacted}$ + $V_{O_2,unreacted}$) cm^3



$15 + V_{O_2,reacted} + V_{O_2,unreacted} = 15 + (15 + V_{O_2,unreacted})$

$\Rightarrow V_{O_2,reacted} = 15\ cm^3$

$\Rightarrow 2\ V_{CH_4} + \frac{1}{2}(15 - V_{CH_4}) = 15$

$\Rightarrow V_{CH_4} = 5\ cm^3$, which is $\frac{5}{15} \times 100 =$ **<u>33.3 %</u>** of the mixture

11 Answer: **D**

Worked Solution:

$\Delta H_r^{\ominus} = \sum m\Delta H_f^{\ominus}$(pdts) − $\sum n\Delta H_f^{\ominus}$(rxts)

$\Delta H_f^{\ominus}(MgCl_2) = \Delta H_r^{\ominus} + \Delta H_f^{\ominus}(HCl)$

The standard enthalpy change of formation of elements in their standard states at 298 K and 1 bar is, by definition, ***<u>zero</u>***

12 Answer: **C**

<u>Worked Solution</u>:

The rate of the reaction depends on the rate of the slow step, i.e.

$$\text{rate} = k' [\mathbf{B}] [\mathbf{C}]$$

However, the rate equation for the overall reaction should be in terms of reactant concentrations only. (Note that **C** and **D** are reaction intermediates.)

Since step 1 of the mechanism is an equilibrium, 2**A** ⇌ **C**, we can write an expression for its equilibrium constant,

$$K_{\text{step 1}} = \frac{[\mathbf{C}]}{[\mathbf{A}]^2}$$

Rearranging, $[\mathbf{C}] = K_{\text{step 1}} [\mathbf{A}]^2$

The rate equation then becomes

$$\text{Rate} = k' [\mathbf{B}] (K_{\text{step 1}} [\mathbf{A}]^2) = k [\mathbf{A}]^2 [\mathbf{B}]$$

where $k = k' \times K_{\text{step 1}}$

13 Answer: **B**

Worked Solution:

Graph of [**W**] against time is a downward-sloping straight line with constant gradient.

⇒ Rate of reaction is independent of [**W**].

⇒ Reaction is zero order wrt [**W**].

[**W**] / mol dm^{-3}	[**V**] / mol dm^{-3}	Rate of reaction / mol dm^{-3} min^{-1}
0.10	1.0	$\frac{0.10}{20}$ = 0.0050
0.10	2.0	$\frac{0.10}{10}$ = 0.010

When [**V**] × 2, while [**W**] is unchanged, rate of reaction × 2

⇒ Reaction is first order wrt [**V**].

Order of reaction wrt [**X**] cannot be determined from the graph.

∴ Only Statements 1 & 2 are correct.

14 Answer: **D**

Worked Solution:

	$BiCl_3$(aq)	+	$H_2O(l)$	⇌	$BiOCl$(s)	+	$2HCl$(aq)
Initial amt / mol	0.1		−		−		0
Change in amt / mol	−0.02		−		+0.02		+2(0.02)
Eqm amt / mol	0.08		−		0.02		2(0.02)

$$K_c = \frac{[HCl]^2}{[BiCl_3]} = \frac{(\frac{2 \times 0.02}{2})^2}{\frac{0.08}{2}}$$

15 Answer: **B**

Worked Solution: When temp increases, by LCP, position of eqm shifts to the right to favour the endothermic reaction to absorb heat. So K_a increases. Since $K_a = \alpha^2 c$, degree of dissociation also increases.

16 Answer: **A**

Worked Solution:

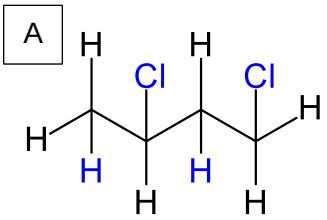
Solubility product is only affected by changes in temperature.

17 Answer: **C**

Worked Solution:

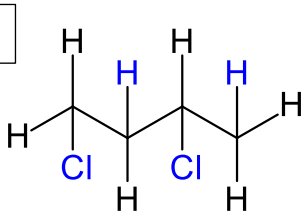
Products formed:

A



secondary chloroalkane

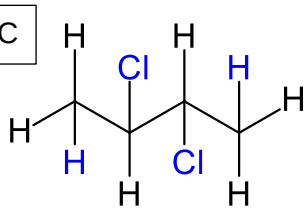
B



Isomer A and B are the same.

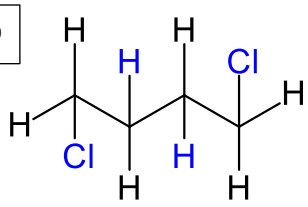
No. of constitutional isomers: 3

C



secondary chloroalkane

D



Primary chloroalkane

18 Answer: **A**

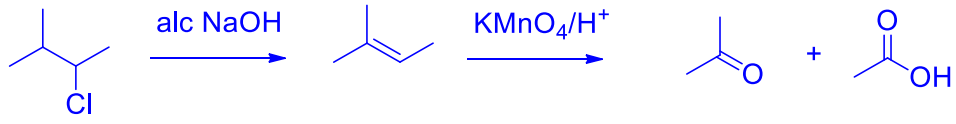
Worked Solution:

Due to the delocalisation of π electrons, the π electron cloud in benzene is less susceptible to an electrophilic attack than a localised π electron cloud in cyclohexene.

Thus, cyclohexene reacts readily with a weak electrophile like a polarised Br_2, while benzene requires a Lewis acid catalyst to generate a stronger electrophile, Br^+, before a reaction with bromine can occur.

19 Answer: **B**

Worked Solution:

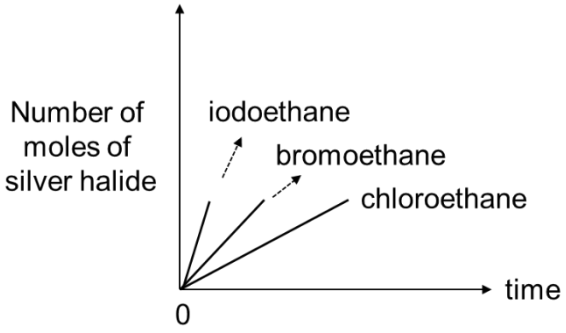


20 Answer: **D**

Worked Solution:

Each mole of dichloroethane provides 2x the amount of AgCl as chloroethane, for the same amount of time of the experiment.

For bromoethane and iodoethane, the rate of reaction is faster due to weaker C−X bond, but the amount of AgX produced is the same as chloroethane, so the graph should be:



21 Answer: **C**

Worked Solution:

	−OH ≡ Na ≡ ½H_2	−CO_2H ≡ $NaHCO_3$ ≡ CO_2
alcohol	√	X
phenol	√	X
acid	√	√

Option	H_2 from Na	CO_2 from $NaHCO_3$
A	1	0
B	1	0
C	1	1
D	1	2

22 Answer: **B**

Worked Solution:

A × **2,4-DNPH:** positive test for carbonyl group in vanillin and cinnamaldehyde

B √ **Fehling's solution:** positive test for aliphatic aldehyde group in cinnamaldehyde and negative for benzaldehyde in vanillin

C × **Hot acidified $K_2Cr_2O_7$:** positive test for aldehyde group in vanillin and cinnamaldehyde.

D × **Tollens' reagent:** positive test for both

23 Answer: **D**

Worked Solution:

Order of decreasing acidity: carboxylic acids > phenols > alcohols

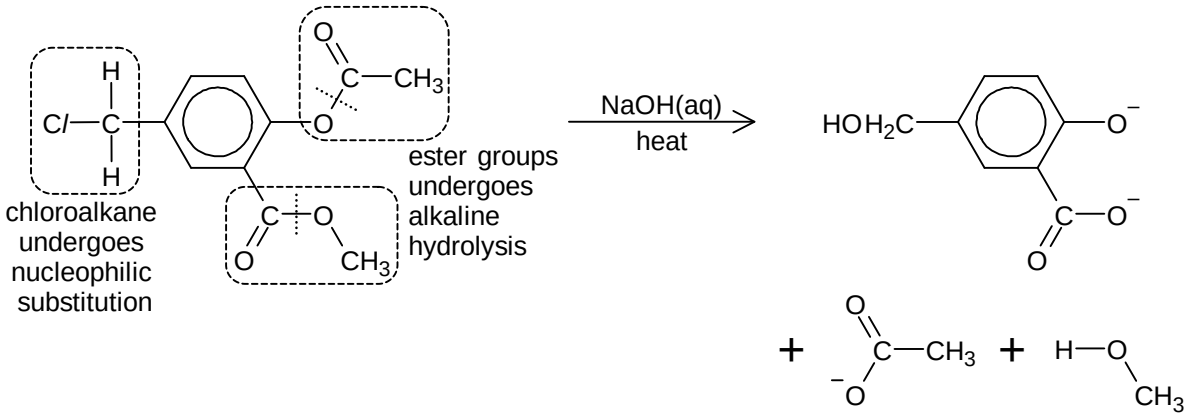
[Refer to page 5, Section 3.1 (Comparison of Acid strength between RCOOH, phenol and alcohols) in the Carboxylic Acids lecture notes.]

2-chlorobenzoic acid is more acidic than benzoic acid. 2-chlorobenzoic acid has an electron-withdrawing C*l* atom which disperses the negative charge on the 2-chlorobenzoate ion and helps to stabilise it to a larger extent than the benzoate ion.

∴ Order of decreasing acidity: 3 > 2 > 1 > 4

24 Answer: **C**

Worked Solution:



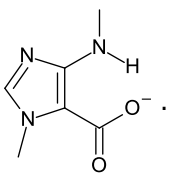
25 Answer: **A**

Worked Solution:

1 N^2 is the less basic as it is an amide where the lone pair of electrons on N is delocalised over the O−C−N bond and hence is not available for dative bonding with a proton.

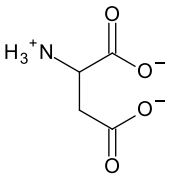
N^1 is the more basic as the lone pair of electrons on N is in an orbital that is perpendicular to the C=C and hence cannot be delocalised. The lone pair of electrons is available for dative bonding to H^+.

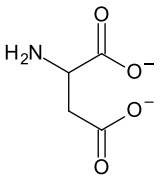
2 Caffeine does not react with ethanoyl chloride as there are no H attached to N^1 and N^2.

3 Caffeine undergo alkaline hydrolysis to form only one mole of methylamine and  .

26 Answer: **D**

Worked Solution:

At pH = 4, the major species of aspartic acid present is  . Since it has a net charge of −1, it will migrate to the positive electrode (anode).

At pH = 11, the major species is  . Since it is doubly charged, it would migrate faster than if the pH = 4.

27 Answer: **C**

Worked Solution:

Hexacyanoferrate(III) is an oxidising agent, NOT an reducing agent.

The stronger the reducing agent, the more likely it will undergo oxidation, the less positive/more negative the $E^{\ominus}$ will be.

$E^{\ominus}(NO_3^-/NO_2) = +0.81\ V < E^{\ominus}(VO_2^+/VO^{2+}) = +1.00\ V < E^{\ominus}(MnO_2/Mn^{2+}) = +1.23V$

28 Answer: **B**

Electrode half-equation	$E^{\ominus}$ / V
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$Cu^{2+}(aq) + 2e^- \leftrightharpoons Cu(s)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	+0.54
$S_2O_8^{2-}(aq) + 2e^- \rightarrow 2SO_4^{2-}(aq)$	+2.01

Worked Solution:

An ion is deemed suitable to catalyse the reaction if it is able to be consumed and regenerated, i.e. the $E^{\ominus}$ value is in between that of 0.54V and +2.01V.

Cu^{2+} cannot oxidise iodide in the first place due to non-spontaneous reaction (0.34 – 0.54 < 0), so it cannot be consumed and is not a suitable catalyst.

Co^{2+}: reacts with peroxydisulfate to form SO_4^{2-} and Co^{3+} ($E^{\ominus}_{cell}$ = 2.01 – 1.82 > 0) and Co^{3+} then reacts with iodide to give iodine and regenerates Co^{2+} ($E^{\ominus}_{cell}$ = 1.82 – 0.54 > 0).

Fe^{2+}: reacts with peroxydisulfate to form SO_4^{2-} and Fe^{3+} ($E^{\ominus}_{cell}$ = 2.01 – 0.77 > 0) and Fe^{3+} then reacts with iodide to give iodine and regenerates Co^{2+} ($E^{\ominus}_{cell}$ = 0.77 – 0.54 > 0).

Fe^{3+}: reacts with iodide to give iodine and Fe^{2+} ($E^{\ominus}_{cell}$ = 0.77 – 0.54 > 0) and Fe^{2+} then reacts with peroxydisulfate to form SO_4^{2-} and regenerates Fe^{3+} ($E^{\ominus}_{cell}$ = 2.01 – 0.77 > 0).

29 Answer: **C**

Worked Solution:

The maximum oxidation state of vanadium is found in VO_2^+

Finely divided Fe is used as a catalyst in the manufacture of ammonia

$E^{\ominus}_{Zn2+/Zn} = -0.76V$; $E^{\ominus}_{V3+/V2+} = -0.26V$; $E^{\ominus}_{V2+/V} = -1.20V$

Vanadium is denser than calcium.

30 Answer: **A**

Worked Solution:

ethylenediamine (en) > $H_2NCH_2CO_2^-$ (gly^-) > $C_2O_4^{2-}$

$[Co(gly)_3]$ complex is violet, the complex absorbs yellow light (560−590 nm)

$[Co(C_2O_4)_3]^{3-}$(aq) a smaller energy gap between the two sets of d-orbitals in a transition metal complex, the complex absorbs a longer wavelength of light (590−700 nm), colour of complex should be **blue or green**

and $[Co(en)_3]^{3+}$(aq), a larger energy gap between the two sets of d-orbitals in a transition metal complex, the complex absorbs a shorter wavelength light (400−590 nm), colour of complex should be **yellow, orange, red**