Catholic Junior College

JC 2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

9729/01

Paper 1 Multiple Choice

September 2021

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

WORKED SOLUTIONS

General comments

Students found questions **2, 3, 14, 18, 19, 20, 22, 23, 24, 25, and 30** to be the **most challenging**.

(You should revisit and fully understand these even you got it correct)

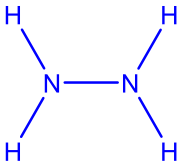
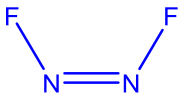
This document consists of **12** printed pages.

1 Nitrogen exists as a diatomic molecule, N_2. Hydrazine, N_2H_4, and dinitrogen difluoride, N_2F_2, are compounds of nitrogen.

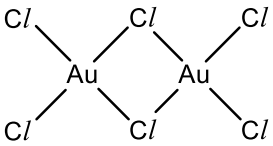
Which of the following gives the correct number of π bonds in N_2, N_2H_4 and N_2F_2?

	number of π bonds in N_2	number of π bonds in N_2H_4	number of π bonds in N_2F_2
A	2	0	1
B	2	1	1
C	1	1	2
D	3	0	2

(Inspired by H1 2020 MCQ6)
Concept: Chemical Bonding, σ and π bonds
Answer: A

	number of π bonds in N_2 	number of π bonds in N_2H_4 	number of π bonds in N_2F_2  (either cis or trans)
A	(1σ), 2π	(5σ), no π	(3σ), 1π

2 Aluminium chloride is a covalent compound that forms a dimer with the formula Al_2Cl_6. A compound of gold and chlorine has a similar molecular formula of Au_2Cl_6 and has the following structure:



The three statements below are properties of the gold compound, Au_2Cl_6.

1 The oxidation state of the metal is +3.
2 The dimer exists in the vapour phase.
3 The Cl-Au-Cl bond angle is 90°.

Which property described is **different** from that of the aluminium compound, Al_2Cl_6?

A 1 and 2 only
B 1, 2 and 3
C 3 only
D 2 and 3 only

(Inspired by H2 2018 MCQ2)
Concept: Chemical Bonding, Al_2Cl_6.
Answer: C

1. This is a similar property to Al_2Cl_6. Chlorine is more electronegative than Al. Each Al also has an oxidation state of +3 as each Cl has an oxidation state of -1.
2. This is a similar property to Al_2Cl_6. Al_2Cl_6 dimer exists in the gas phase.
3. Not similar. The Cl-Al-Cl bond angle is 109.5°.

3 The table below lists three compounds:

compound	boiling point / °C
CH_3CH_2–S–H	35
CH_3–S–CH_3	37
CH_3CH_2–O–H	78

Which of the following statements about the compounds is true?

A The C–S–H bond angle is larger than the C–O–H bond angle because S is larger than O.
B CH_3CH_2–S–H has weaker intermolecular hydrogen bonding than CH_3CH_2–O–H.
C CH_3CH_2–S–H and CH_3–S–CH_3 have similar boiling points because they have intermolecular permanent dipole – permanent dipole forces of attraction of similar strengths.
D CH_3CH_2–O–H has the highest boiling point because the O–H bond energy is higher than the S–H bond energy.

(Inspired from 2019 H2 A level P3 Q2(f)(i))
Concept: Chemical Bonding, Bond angle and IMF
Answer: C

A The C–S–H bond angles are smaller than the C–O–H bond angle because S is less electronegative than O. The valence electrons around S will be further away compared to the valence electrons in O. As a result, there is weaker bond pair – bond pair repulsion around S than around O, giving rise to a smaller bond angle.
B CH_3CH_2–S–H does not have intermolecular hydrogen bonding as the H present in the molecule is not bonded to F, O or N.
C True. Both are isomers of each other (same number of electrons) and both are polar molecules.
D CH_3CH_2–O–H has the highest boiling point due to stronger intermolecular hydrogen bonding which is absent in the other two compounds. The strength of covalent bonds is not relevant to the boiling point for simple molecules.

4 *Use of the Data Booklet is relevant to this question.*

An isotope of a metal, **Z**, undergoes radioactive decay to form helium and an element hafnium, Hf, according to the following equation.

$$\mathbf{Z} \longrightarrow {}^{4}_{2}\mathrm{He} + \mathrm{Hf}$$

Given that Hf has a nucleon number of 176, which row correctly shows the identity and composition of **Z**?

	identity of **Z**	number of nucleons in **Z**
A	tungsten	180
B	tungsten	178
C	osmium	180
D	osmium	178

Concept: Atomic Structure, sub-atomic particles.
Answer: A
From *Data Booklet*, the atomic number of hafnium is 72. Given that the nucleon number is 176, this will be a more detailed equation of the decay:

$$\mathrm{Z} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{176}_{72}\mathrm{Hf}$$

Hence, proton number of Z is 72 + 2 = 74. This correlates to tungsten.
The nucleon number of Z is 176 + 4 = 180

5 *Use of the Data Booklet is relevant to this question.*

The first six ionisation energies of an element, **Y**, in kJ mol^{-1} are shown.

738; 1451; 7733; 10543; 13630; 18020

Y forms an oxide by heating **Y** with oxygen gas.
What is the *spdf* electronic configuration of **Y** in its oxide form?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
B $1s^2\ 2s^2\ 2p^6$
C $1s^2\ 2s^2\ 2p^6\ 3s^2$
D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Concept: Atomic Structure, ionisation energy.
Answer: B
The significant increase from the second to the third ionisation energy indicates that Y is from Group 2.
From Data Booklet, the ionisation energies match Mg ($1s^2\ 2s^2\ 2p^6\ 3s^2$) most closely.

When Mg forms MgO, it loses its two valence electrons and hence its electronic configuration is $1s^2\ 2s^2\ 2p^6$.

6 What is the element that has a **second** ionisation energy lower than that of each of the elements either side of it in the Periodic Table?

A boron **B** nitrogen **C** oxygen **D** fluorine

(Inspired from 2010 H1 A level MCQ3)
Concept: Atomic Structure. Second Ionisation energy
Answer: D

Second IE is $F^+ \rightarrow F^{2+} + e^-$

Element before F: O		Element after F: Ne
O^+: $1s^2 2s^2\ 2p_x^1 2p_y^1 2p_z^1$	F^+: $1s^2\ 2s^2\ 2p_x^2 2p_y^1 2p_z^1$	Ne^+: $1s^2 2s^2\ 2p_x^2 2p_y^2 2p_z^1$

Comparing F and O:
Less energy is required to remove a paired $2p_x$ electron from F^+ due to interelectronic repulsion. Hence second IE of F is less than O.

Comparing F and Ne:
Less energy is required to remove the electron from F^+ because it has a lower nuclear charge than Ne and a smaller ionic size than Ne^+.

Alternatively, check the Data Booklet:
Second IE values in kJ mol^{-1}:

O	F	Ne
3390	3370	3950

7 Analysis of a mixture of two sulfur-containing gases show that hydrogen sulfide, H_2S, and carbon sulfide, CS_2, are present in a 3 : 1 mole ratio.

This mixture is burned in excess oxygen.
What will be the CO_2 : SO_2 mole ratio in the mixture obtained after complete combustion?

A 1 : 2 **B** 1 : 3 **C** 1 : 4 **D** 1 : 5

2016 P1 Q2 modified
Concept: Mole concept & stoichiometry
Ans: D

Let amount of H_2S be $3x$ mol and CS_2 be x mol,

$H_2S + \frac{3}{2}O_2 \rightarrow SO_2 + H_2O$

Amount of SO_2 produced by H_2S = $3x$ mol

$CS_2 + 3O_2 \rightarrow 2SO_2 + CO_2$

Amount of SO_2 produced by CS_2 = $2x$ mol, Amount of CO_2 produced = x mol

Hence, mole ratio of CO_2 : SO_2 in the mixture after complete combustion will be x : $(3x + 2x)$ = **1 : 5**

8 *Use of the Data Booklet is relevant to this question.*

A mordant is a soluble salt which forms an acidic aqueous solution and improves the binding of the molecules of a dyestuff to a material.

Which solution is least likely to be used as a mordant in the dyeing process?

A sodium sulfate
B magnesium sulfate
C aluminium sulfate
D iron(II) sulfate

2018 A-level P1 Q13 modified
Concept: Periodic Table; extension of reaction of Period 3 chlorides with water
Ans: A

Recall from Periodic Table, pH of $Al^{3+}(aq)$ = 3, pH of $Mg^{2+}(aq)$ = 6.5

Al^{3+}, Mg^{2+} and Fe^{2+} can undergo hydrolysis to give H^+ due to their high charge densities, polarising an O-H bond in H_2O.

Charge density of Al^{3+} ($\propto \frac{+3}{0.050}$) is the highest among all the cations in the question.

Charge density of Fe^{2+} ($\propto \frac{+2}{0.061}$) is similar to the charge density of Mg^{2+} ($\propto \frac{+2}{0.065}$) hence it can also undergo hydrolysis.

Na^+ is not able to undergo hydrolysis due to its low charge density ($\propto \frac{+1}{0.095}$), hence sodium sulfate is a neutral solution and is unlikely to be used as a mordant.

9 Element **X** is in Period 3 of the Periodic Table. The following four statements describe the properties of element **X** or its compounds.

Three statements are correct descriptions. One of the statements is not correct because it does not fit with the other three.

Which statement is **not** correct?

A Element **X** is a solid at room temperature which conducts electricity.

B The chloride of element **X** reacts with water to give an acidic solution.

C The oxide of element **X** reacts in water to give an acidic solution.

D Adding NaOH(aq) to the solution resulting from the reaction of **X**Cl_3 with water produces a white precipitate which is soluble in an excess of NaOH (aq).

2017 P1 Q15 modified
Concept: Periodic Table, trends and variation in chemical and physical properties
Ans: C

Element **X** is A*l*.

Al_2O_3 in insoluble in water hence it will not react with water to give an alkaline solution.

Al^{3+} reacts with OH^- to form white ppt of A*l*$(OH)_3$. In the presence of excess OH^-, the A*l*$(OH)_3$ ppt will react further to form soluble complex A*l*$(OH)_4^-$ which explains the solubility of the white ppt in excess NaOH(aq).

10 Which property generally increases down Group 2?

A charge density of M^{2+} ion
B electronegativity
C melting point
D thermal stability of the carbonate

2015 P1 Q15 modifed
Concept: Periodic Table; Group 2 properties
Ans: D

A Charge density of M^{2+} ion decreases since +2 charge remains constant but cationic radius increases.
B Electronegativity decreases down the group as the distance between valence electron shell and the nucleus increases.
C Melting point decreases down the group as the cationic radius of M^{2+} ions increases, hence the strength of electrostatic attractions between the sea of delocalised electrons and M^{2+} ions decreases, resulting in less energy needed to overcome the metallic bonds.
D Thermal stability of the carbonate increases down Group 2, as the polarising power of M^{2+} ion decreases down the group, resulting in the decreasing ability of M^{2+} ion to distort the electron cloud of the CO_3^{2-} anion.

11 A comproportionation reaction is a chemical reaction where two reactants, each containing the same element but with a different oxidation number, form a product in which the elements involved reach the same oxidation number.

2 mol of hydrogen sulfide, H_2S, react with 1 mol of another sulfur-containing compound to form 3 mol of elemental sulfur, S, in a comproportionation reaction.

What is a possible identity of the sulfur-containing compound?

A SO_2 **B** SO_3 **C** H_2SO_4 **D** SCl_2

2018 P1 Q10 modified
Concept: Mole concept & stoichiometry, redox
Ans: A

	H_2S +	S^x	→ S
Mole ratio	2	1	3

$\therefore 2H_2S + S^x \rightarrow 3S$ (not balanced)

By figuring out the changes in the oxidation states of S during the redox reaction,

$2H_2S$ +	S^x	→ 3S
2(–2)	(+x)	3(0)
–4	+4	0

Since $2H_2S \equiv 4\ e^- \equiv 1S^x$
1 mole of S would have gained 4 moles of electrons to form 1 mole of S

Thus, oxidation number of S in the sulfur-containing compound = +4
Hence the sulfur-containing compound is SO_2.

O.N. of S in SO_2 = +4
O.N. of S in SO_3 = +6
O.N of S in H_2SO_4 = +6
O.N. of S in SCl_2 = +2

12 *Use of the Data Booklet is relevant to this question.*

Dinitrogen oxide, N=N=O, burns in ethyne, C_2H_2, to produce water vapour, carbon dioxide and nitrogen gas according to the following equation.

$$5N_2O(g) + C_2H_2(g) \rightarrow H_2O(g) + 2CO_2(g) + 5N_2(g)$$

The enthalpy change for this reaction is –1668 kJ mol^{-1} and in dinitrogen oxide, the N=N bond energy has a value of +418 kJ mol^{-1}. With reference to other appropriate bond energy data from the *Data Booklet*, what is the N=O bond energy in dinitrogen oxide?

A 344 kJ mol^{-1} **C** 1354 kJ mol^{-1}

B 688 kJ mol^{-1} **D** 3442 kJ mol^{-1}

Concept: Chemical Energetics (Bond Energy)
Answer: B

5(N=N=O) + H–C≡C–H → H–O–H + 2O=C=O + 5N≡N

$H_{rxn} = \sum BE(reactants) - \sum BE(products)$

$-1668 = [(5 \times 418) + 5BE(N=O) + (2 \times 410) + 840] - [(2 \times 460) + (4 \times 805) + (5 \times 944)]$

$BE(N=O) = 688.4$ kJ mol^{-1}

13 Which of the following is an endothermic process?

1 The combustion of methane
2 The condensation of steam
3 The electrolysis of water
4 The sublimation of iodine

A 1 and 2 only
B 2 and 3 only
C 3 and 4 only
D 1 and 4 only

Concept: Chemical Energetics, Endothermic reactions

Answer: C (3 and 4 only)

1: Combustion is always exothermic as it releases heat energy to the surroundings when it forms more stable compounds relative to the reactants after combustion.
2: Bond formation due to formation of water in liquid state (hydrogen bonds between water molecules) has occurred, thus condensation is an exothermic process.
3: The electrolysis of water is an endothermic reaction (electrical energy supplied) with the following equation: $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$
4: $I_2(s)$ is converted to I_2 vapour when the intermolecular instantaneous diploe – induced dipole forces of attraction holding the I_2 molecules in a crystal lattice are broken. Thus, it is an endothermic process.

14 At 1200 K, in the presence of gold catalyst, dinitrogen oxide, N_2O, decomposes according to the equation below.

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

The following data is obtained in an experiment.

time, *t* / s	0	1030	2360	4230	7430
partial pressure of N_2O / kPa	25.0	20.0	15.0	10.0	5.0

Which of the following statements is correct?

1 The partial pressure of N_2O at any given time is not affected by temperature.
2 The reaction is first order with respect to N_2O.
3 The value of the rate constant remains unchanged in the absence of gold.
4 The total pressure at the completion of the reaction can be determined from the above data.

A 1 and 2 only
B 1 and 3 only
C 2 and 4 only
D 3 and 4 only

Concept: Reaction Kinetics

Answer: C (2 and 4 only)

1: pV = nRT, partial pressure is affected by temperature
2: The time taken for partial pressure of N_2O to decrease from 20.0 to 10.0 kPa (4230 – 1030 = 3200 s) is same as time taken for partial pressure of N_2O to decrease from 10.0 to 5.0 kPa (4230 – 7430 = 3200 s), implying constant half life and hence 1st order wrt N_2O.
3: From Arrhenius equation, $k = Ae^{-\frac{E_a}{RT}}$, k is affected by activation energy, which in turn is lowered by catalyst.
4: From stoichiometric equation, the total pressure of all the products at completion of reaction = 3/2 x pressure of N_2O at the start of reaction.

15 The reaction shown below takes place via a one-step mechanism.

$$A(g) + 2B(g) \rightleftharpoons C(g)$$

Which of the following statements is most likely to be correct?

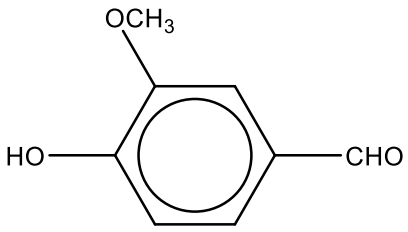
1 The yield of C increases at lower pressure.
2 The yield of C decreases when the volume of the reaction vessel is halved.
3 The equilibrium concentration of C is given by the expression: $[C] = K_c[A][B]^2$
4 The rate of the forward reaction is given by the expression: rate = $k[A][B]^2$

A 1 and 2 only
B 1 and 3 only
C 2 and 4 only
D 3 and 4 only

Concept: Reaction Kinetics, Chemical Equilibria
Answer: D

1: At lower pressure, POE shifts LHS to favour the side with more moles of gas according to LCP. Hence, yield of C decreases.
2: pV = nRT. When volume of reaction vessel is halved, pressure doubles resulting in POE shifting RHS to decrease pressure. Hence, yield of C increases.
3: K_c = [C] / [A] $[B]^2$. Hence, [C] = K_c[A]$[B]^2$
4: If reaction takes place via one-step mechanism, rate = k[A]$[B]^2$

16 Vanillin is the key flavour compound in vanilla, and its structure is shown.



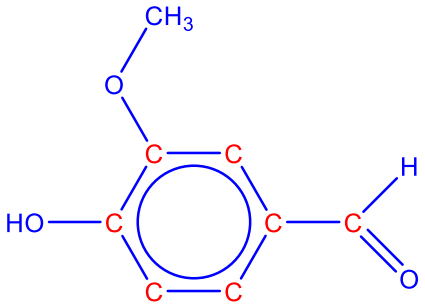
vanillin

How many sp^2 hybridised carbons are there in a molecule of vanillin?

A 5 **B** 6 **C** 7 **D** 8

Concept: Introduction to Organic Chemistry – hybridisation
Ans: C

The 7 sp^2 hybridised carbons are shown in red, each with 3 σ bonds and 1 π bond.

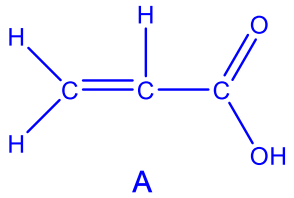


17 A non-cyclic organic compound has the molecular formula $C_3H_4O_2$.
Which combination of functional groups **cannot** be present in this molecule?

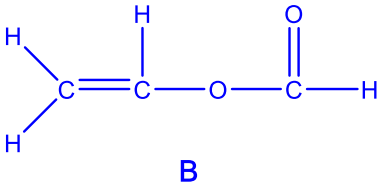
A one alkene and one carboxylic acid group
B one alkene and one ester group
C one alkene and two alcohol groups
D one aldehyde and one ketone group

(inspired by 2013/P1/39)
Concept: Introduction to Organic Chemistry
Ans: C

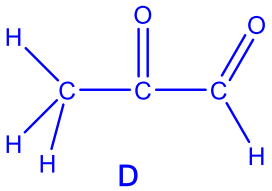
As shown A, B and D are possible, but a molecule with an alkene and two alcohol groups would need 2 more H atoms, hence molecular formula $C_3H_6O_2$ (one more degree of saturation)



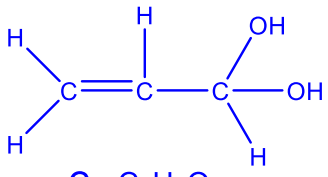
A



B

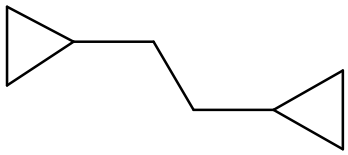


D



C - $C_3H_6O_2$

18 Compound **W**, C_8H_{14}, reacts with chlorine gas in the presence of *uv* light.

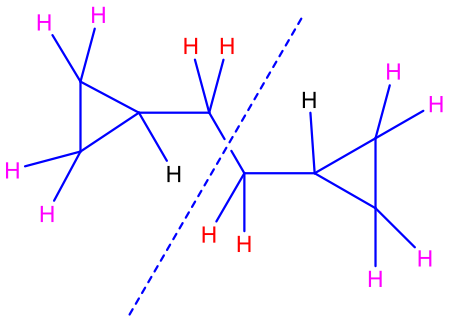

W

Which of the following statements about this reaction is correct?
1 The maximum number of mono-chlorinated constitutional isomers with formula $C_8H_{13}Cl$ is 3.
2 $C_{16}H_{28}$ is present in small quantities in the product.
3 Homolytic fission only occurs in the initiation step.

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

Concept: Alkanes
Ans: D

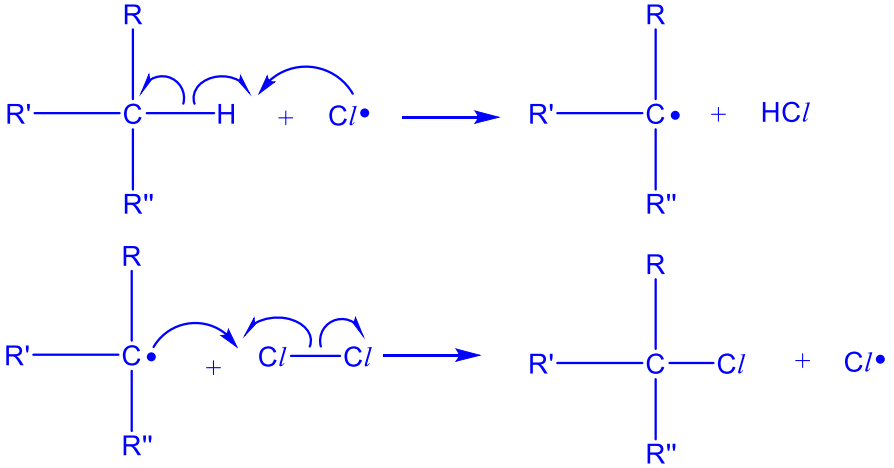
Statement **1** is correct as there are 3 types of equivalent H atoms, as shown.



Statement **2** is wrong, $C_{16}H_{26}$ is formed in small quantities in the reaction.
Statement **3** is wrong, homolytic fission occurs in the propagation step too.
Mechanism:

Stage I: Initiation

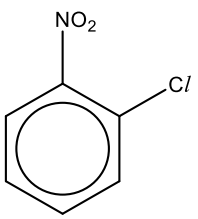
Stage II: Propagation



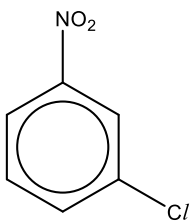
19 When nitrobenzene is heated with BrCl and $AlBr_3$, a mono-halogenated product is formed.

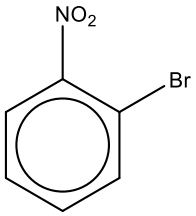
Which product is most likely to be formed?

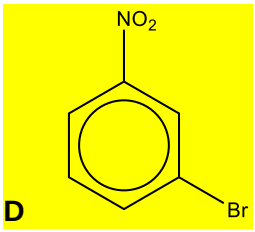
A



B



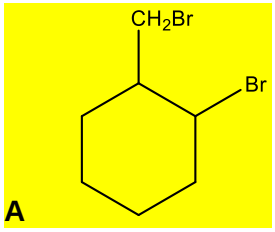
C 

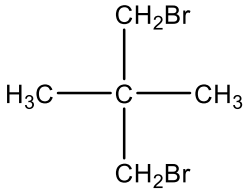
D 

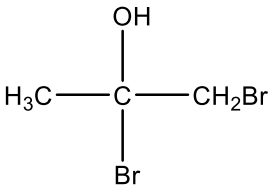
(inspired by 2017 P3 Q1d)
Concept: Arenes, electrophilic substitution
Ans: D

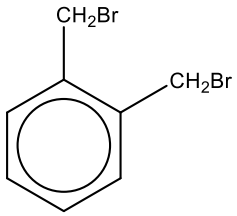
In the presence of $AlBr_3$ catalyst, electrophilic substitution occurs.
In the first step, Br^+ is formed as the electrophile as it is less electronegative than C*l*.
Also, $–NO_2$ is 3-directing so Br will be substituted in the 3rd position, not the 2nd position.

20 1 mol of organic compound **V** reacts with ethanolic sodium hydroxide to form 2 mol of HBr. What could **V** be?

A 

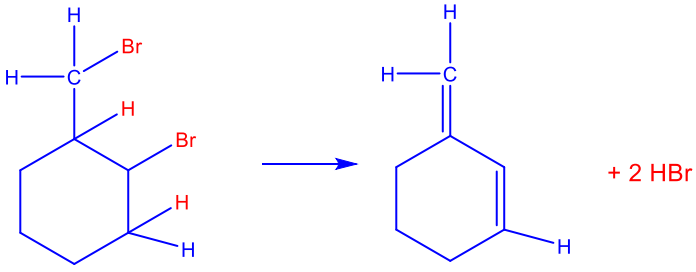
B 

C 

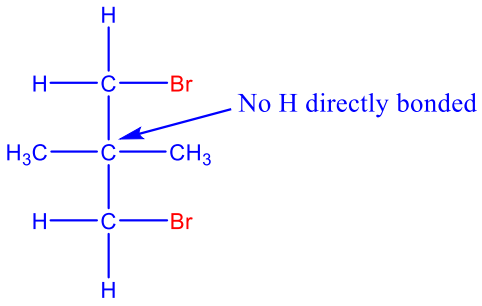
D 

Concept: Halogen derivatives, elimination
Ans: A

Option **A** can undergo elimination as shown. (note that this is a cyclohexane ring, not benzene)

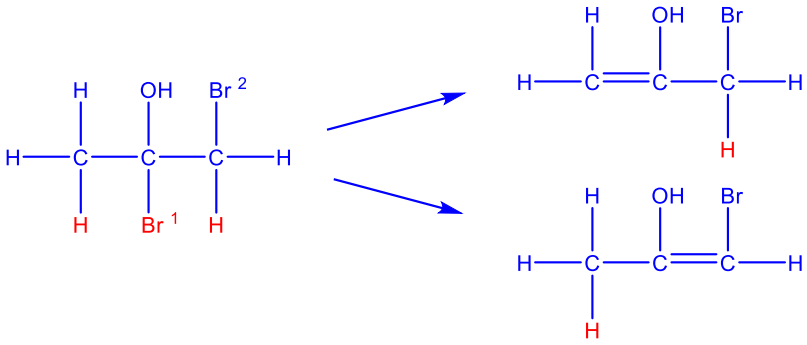
A 

For option **B**, the carbons with Br attached do not have an adjacent carbon with H to be eliminated.



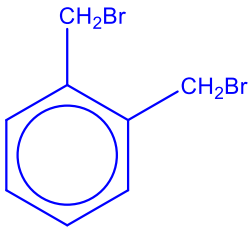
B

For option **C**, only 1 mole of HBr can be eliminated from Br [1] but not Br [2].



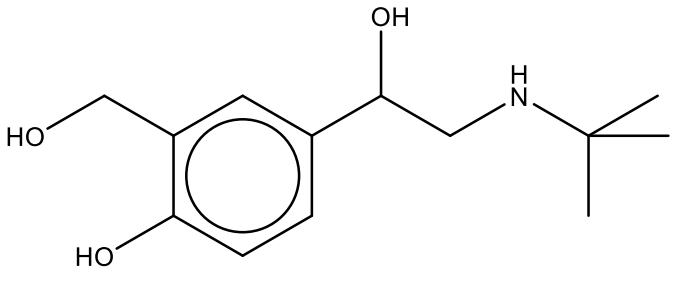
C

For option **D**, the adjacent carbons (on the benzene ring) to the carbons with Br do not have any H to undergo elimination.



D

21 Salbutamol is a common medicine used to alleviate asthma attacks.



salbutamol

Which statement about 1 mol of salbutamol is **incorrect**?

A It reacts with 4 mol of ethanoyl chloride, CH_3COCl, to form 3 ester and 1 amide group.

B It reacts with excess acidified $K_2Cr_2O_7$(aq) to form 1 carboxylic acid and 1 ketone group.

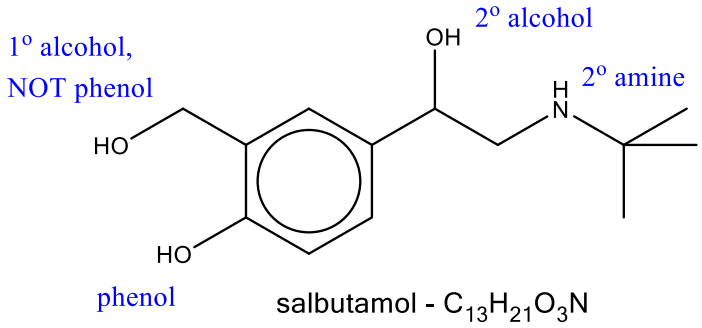
C It reacts with 3 mol of sodium metal.

D It reacts with 2 mol of NaOH(aq).

(inspired by 2013 P1 Q26)

Concept: ROH + RCO_2H + derivatives

Ans: D



A – alcohols and the phenol react with acyl chlorides to form esters, while the amine reacts to form an amide.

B – the 1° and 2° alcohol can be oxidized to form a carboxylic acid and ketone respectively.

C – both alcohols and phenol react with Na(s)

D – only phenol reacts with NaOH(aq)

ROH + RCO_2H + derivatives

22 Which of the following shows the correct order of decreasing pK_a?

A	C_6H_5OH	>	CH_3CH_2OCOH	>	$CH_3CH_2CO_2H$	>	CH_3CHFCO_2H
B	CH_3CH_2OCOH	>	C_6H_5OH	>	$CH_3CH_2CO_2H$	>	CH_3CHFCO_2H
C	CH_3CHFCO_2H	>	$CH_3CH_2CO_2H$	>	C_6H_5OH	>	CH_3CH_2OCOH
D	CH_3CH_2OCOH	>	CH_3CHFCO_2H	>	$CH_3CH_2CO_2H$	>	C_6H_5OH

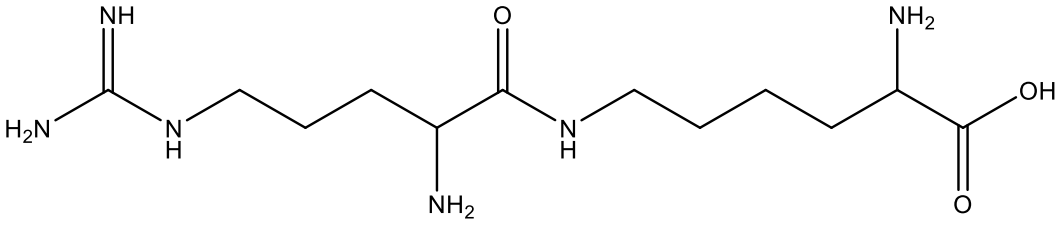
Answer: B

Decreasing pK_a ⇒ increasing K_a ⇒ increasing acidity.

CH_3CH_2OCOH (ester) is neutral; carboxylic acid ($CH_3CH_2CO_2H$) is more acidic than phenol (C_6H_5OH) and electron-withdrawing group (F) in CH_3CHFCO_2H will further stabilise the carboxylate ion, making CH_3CHFCO_2H the strongest acid.

Nitrogen compound

23 Compound **U** is a by-product formed in the body to counteract the effect of the drug administered to treat herpes.



Compound **U**

Which one of the following statements about compound **U** is correct?

A **U** undergoes nucleophilic addition with chloroethane.

B 1 mol of **U** can be hydrolysed to produce 2 mol of amino acids.

C 1 mol of **U** can react with 6 mol of hydrochloric acid at room temperature.

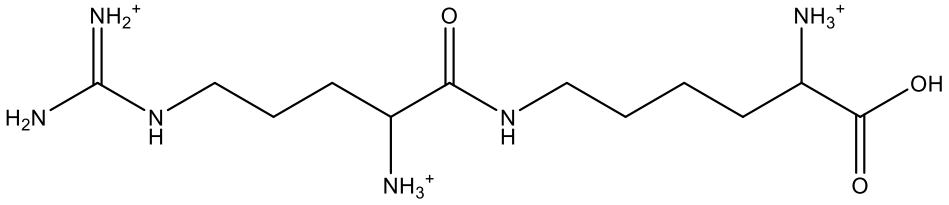
D When an aqueous solution of **U** at pH 3 is analysed by electrophoresis, it is found near the anode.

Answer: B

A Incorrect – amine groups in **U** undergo nucleophilic substitution with chloroethane

B Correct – amide group (peptide linkage) hydrolysed to give two amino acids.

C Incorrect – only 3 amino groups react with hydrochloric acid and get protonated as shown below; the amide group (neutral) does not react with hydrochloric acid at r.t.



D Incorrect – At pH 3, amine groups are protonated and **U** is likely to have a net positive charge and so, is likely to be found near the cathode.

Simple elucidation

24 A compound **T** is boiled with aqueous sodium hydroxide and the resulting mixture cooled and acidified. The final product includes a compound $C_3H_6O_2$ and an alcohol that gives a positive iodoform test.

Which formula could represent compound **T**?

A $CH_3CH_2CO_2CH_2CH_2Cl$

B $CH_3CH_2OCOCH_3$

C $CH_3OCOCH_2COCH_3$

D $CH_3CH_2CO_2CH_2CHClCH_3$

Answer: D

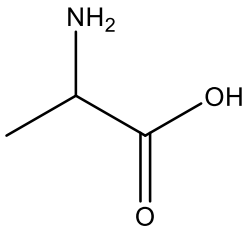
- When boiled with aq. NaOH, hydrolysis of ester and nucleophilic substitution of chloroalkane occurred.

$CH_3CH_2CO_2CH_2\mathbf{CHCl}\mathbf{CH_3} \rightarrow CH_3CH_2CO_2H + HOCH_2\mathbf{CH(OH)CH_3}$
$(C_3H_6O_2)$

- The alcohol formed has $CH_3CH(OH)–$ group and so, gives a positive iodoform test (yellow precipitate of CHI_3 formed).

Nitrogen compound

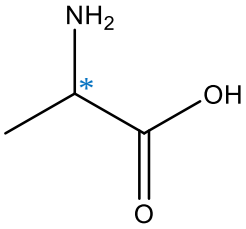
25 Which of the following is **not** a correct statement about *alanine* extracted from silkworm?



alanine

A *Alanine* is able to rotate plane-polarised light.
B *Alanine* has a higher solubility in water than in ether.
C *Alanine* can react with ethanoic acid to give an amide.
D An aqueous solution of *alanine* has a buffering capacity.

Answer: C



A Correct – *alanine* has chiral C (marked *) and is able to rotate plane polarised light.

B Correct – *alanine* exists as zwitterions and so, is more soluble in water.

C Incorrect – with ethanoic acid, *alanine* undergoes acid-base reaction instead of condensation reaction.

D Correct – *alanine*, an amino acid, can act as a buffer.

Transition Element

26 The equation below shows a ligand exchange reaction.

$$[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 4H_2O(l)$$

Which is a possible reason to explain why NH_3 ligands displace H_2O ligands?

A ΔS is positive for the displacement reaction.

B NH_3 is more tightly bound to Cu^{2+} ions than H_2O.

C The energy difference for d→d transition in $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is greater than that in $[Cu(H_2O)_6]^{2+}(aq)$.

D The pH of NH_3 is higher than the pH of $H_2O(l)$

Answer: B

NH_3 is a stronger base (Lewis base) than H_2O and so, forms stronger dative covalent bond with the central Cu^{2+} ion (Lewis acid).

27 *Use of the Data Booklet is relevant to this question.*

The table below gives data about some physical properties of the elements calcium and copper.

Which row gives the correct properties under the correct element?

		calcium	copper
A	melting point / K	1358	1112
B	density / g cm^{-3}	1.54	8.92
C	first ionisation energy / kJ mol^{-1}	745	590
D	atomic radius (metallic) / nm	0.128	0.197

Answer: B

Copper, as a transition metal, has higher melting point and density compared to a typical S block element, calcium. Answer is B.

Values of ionisation energy and atomic radius can be found from the Data Booklet.

28 *Use of the Data Booklet is relevant to this question.*

The silver chloride electrode is a type of reference electrode commonly used in electrochemical measurements. It can be represented as below.

$$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-$$

The reduction potential of Cr^{3+}/Cr^{2+} half-cell is −0.61 V when it is measured using the AgCl /Ag reference electrode at standard conditions.

What is the reduction potential of AgCl /Ag electrode when it is measured against the standard hydrogen electrode as reference?

A +0.80 V **B** +0.41 V **C** +0.20 V **D** –0.41V

Answer: C

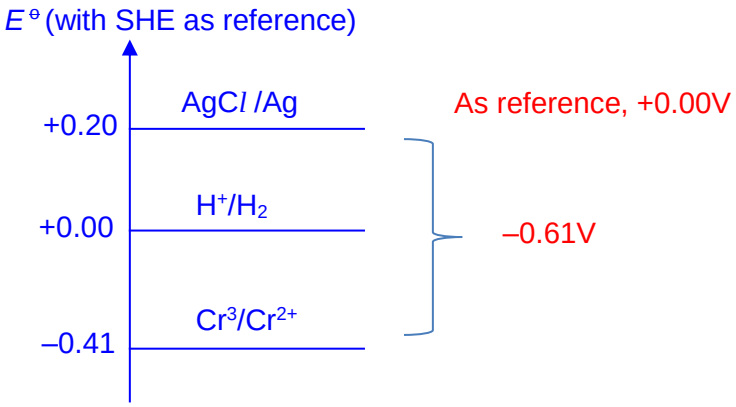
As it is the reduction potential measured, the following formula can be applied:

$E^{\ominus}_{cell} = E^{\ominus}_{Cr3+/Cr2+} - E^{\ominus}_{AgCl\ /Ag} = -0.61$ V

$-0.41 - E^{\ominus}_{AgCl\ /Ag} = -0.61$ V

$E^{\ominus}_{AgCl/Ag} = -0.41 + 0.61$
$= +0.20$ V

Or pictorially,



29 A voltaic cell is set up using the Mg^{2+}/Mg and Fe^{3+}/Fe^{2+} half-cells.

$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$ $\quad E^{\ominus}_{Mg^{2+}/Mg} = -2.38$ V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$ $\quad E^{\ominus}_{Fe^{3+}/Fe^{2+}} = +0.77$ V

Under standard conditions, the cell e.m.f. would be 3.15 V. However, the voltmeter recorded a reading of 3.05 V.

What is the best explanation for this lower e.m.f.?

A a smaller magnesium electrode was used
B a higher concentration of Fe^{3+} was used
C a higher concentration of Mg^{2+} was used
D water evaporated from the Fe^{3+}/Fe^{2+} half-cell

Answer: C

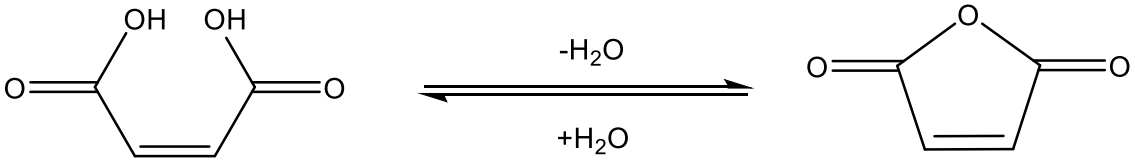
A incorrect – changing the size of a solid does not shift the position of equilibrium

B incorrect – a higher concentration of Fe^{3+} would result in an even greater tendency for reduction, so $E_{Fe^{3+}/Fe^{2+}}$ becomes more positive, and cell e.m.f. becomes more positive as well.

C correct – a higher concentration of Mg^{2+} shifts the position of equilibrium of Mg^{2+}/Mg to the right. $E_{Mg^{2+}/Mg}$ becomes less negative and cell e.m.f. becomes less positive.

D incorrect – concentration of both $Fe^{3+}$and Fe^{2+} increases by the same extent. Hence, there is no shift in position of equilibrium.

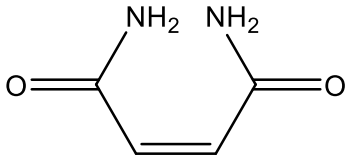
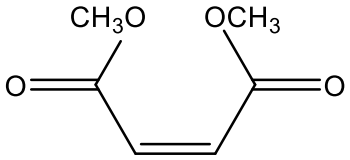
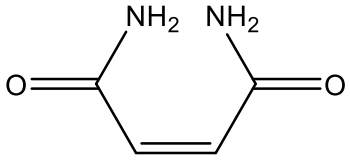
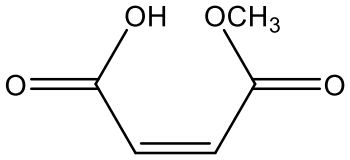
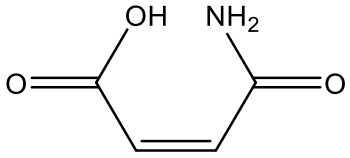
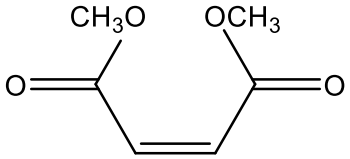
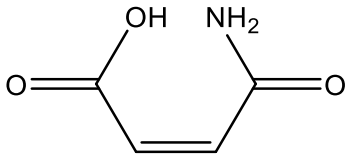
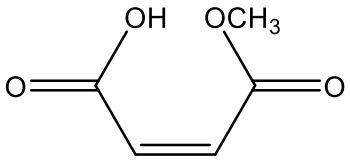
30 Maleic acid loses water on strong heating to form compound **S**. On addition of water to compound **S**, it reforms maleic acid.



maleic acid

compound **S**

Which of the following shows the correct compounds formed when ammonia and methanol are added to compound **S** separately?

	Addition of NH_3	Addition of CH_3OH
A		
B		
C		
D		

Answer: D