EXAM PAPERS PRACTICE

Helping you Achieve Highest Grades in IB

IB Chemistry HL

Question Paper

Fully in-lined with the First Teaching in 2023 & First Assessment Examinations in 2025 & Beyond

Paper: 1 (Multiple-Choice Questions)
- All Topics

Marks: 185

Total Marks: / 185

Suitable for HL Students sitting the 2025 exams onwards
However, SL students may also find these resources useful

Questions

21M.1A.HL.TZ2.40

What information can be deduced from the splitting pattern of ^{1}H NMR signals? [1]
A. total number of hydrogen atoms in a compound
B. number of hydrogen atoms on adjacent atom(s)
C. functional group on which hydrogen atoms are located
D. number of hydrogen atoms in a particular chemical environment

22M.1A.HL.TZ1.23

At equilibrium, the concentrations of chlorine and iodine are both 0.02 mol dm $^{-3}$. [1]

$$\frac{1}{2}\,Cl_2\,(g) + \frac{1}{2}\,I_2\,(g) \rightleftharpoons ICl\,(g) \quad K_c = 454$$

What is the concentration of iodine monochloride, ICl?

A. $\frac{454}{0.02}$
B. 454×0.02
C. $\frac{454}{0.04}$
D. 454×0.04

SPM.1A.HL.TZ0.28

What is the equilibrium constant expression for the following reaction? [1]

$$2SO_3\,(g) \rightleftharpoons 2SO_2\,(g) + O_2\,(g)$$

A. $\frac{2[SO_2]^2 O_2}{[SO_3]^2}$
B. $\frac{[SO_2]^2 + [O_2]}{[SO_3]^2}$
C. $\frac{[SO_3]^2}{[SO_2]^2[O_2]}$
D. $\frac{2[SO_2][O_2]}{2[SO_3]}$

21M.1A.HL.TZ1.27

Which combination will produce an alkaline buffer in water? [1]
A. 0.10 mol NH_3 and 0.05 mol H_2SO_4
B. 0.50 mol NH_3 and 0.10 mol H_2SO_4
C. 0.10 mol CH_3COOH and 0.05 mol NaOH
D. 0.10 mol CH_3COOH and 0.50 mol NaOH

SPM.1A.HL.TZ0.13

Why is copper(II) sulfate blue?

A. Red light is absorbed when electrons are promoted between the orbitals in the split

d-sublevels.
B. Blue light is emitted when electrons fall between the orbitals in the split d-sublevels.
C. Red light is absorbed when electrons fall between the orbitals in the split d-sublevels.
D. Blue light is emitted when electrons are promoted between the orbitals in the split d-sublevels.

[1]

22M.1A.HL.TZ2.27

Which species are **both** Lewis and Brønsted–Lowry bases? [1]

I. CN^-
II. OH^-
III. NH_3

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

21M.1A.HL.TZ2.8

Which factor does **not** affect the colour of a complex ion? [1]
A. temperature of the solution
B. identity of the ligand
C. identity of the metal
D. oxidation number of the metal

22N.1A.HL.TZ0.17

At which temperature could ΔH, ΔS, and ΔG all be positive? [1]

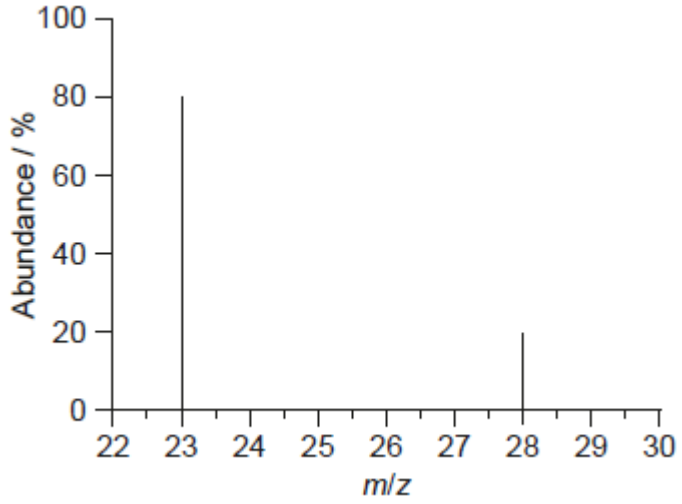
A. High temperatures
B. Low temperatures
C. Any temperature
D. No temperature

22M.1A.HL.TZ1.16

Which compound has the largest value of lattice enthalpy? [1]
A. Na_2O
B. K_2O
C. Na_2S
D. K_2S

22M.1A.HL.TZ2.6

What is the relative atomic mass of an element with the following mass spectrum? [1]



A. 23
B. 24
C. 25
D. 28

22M.1A.HL.TZ2.30

Which $E^{\ominus}$ value, in V, for the reaction $Mn(s) + Zn^{2+}(aq) \rightarrow Mn^{2+}(aq) + Zn(s)$ can be deduced from the following equations?

$Mn(s) + 2Ag^{+}(aq) \rightarrow Mn^{2+}(aq) + 2Ag(s)$ $\quad E^{\ominus} = 1.98$ V
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ $\quad E^{\ominus} = 1.10$ V
$Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$ $\quad E^{\ominus} = 0.46$ V

A. 0.42
B. 1.34
C. 2.62
D. 3.54

[1]

22N.1A.HL.TZ0.11

Which molecule has a tetrahedral molecular geometry? [1]

A. HNO_3
B. SF_4
C. XeF_4
D. XeO_4

21N.1A.HL.TZ0.25

What is the pH of 0.01 mol dm^{-3} KOH (aq)? [1]

A. 1.0
B. 2.0
C. 12.0

D. 13.0

21M.1A.HL.TZ2.30

What would be the electrode potential, $E^{\ominus}$, of the $Mn^{2+}(aq)|Mn(s)$ half-cell if $Fe^{3+}(aq)|Fe^{2+}(aq)$ is used as the reference standard?

$$Mn^{2+}(aq) + 2e^{-} \rightleftharpoons Mn(s) \quad E^{\ominus} = -1.18\ V$$

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

A. −1.95 V
B. −0.41 V
C. +0.41 V
D. +1.95 V

[1]

21N.1A.HL.TZ0.21

The rate equation for a reaction is: [1]

rate = k[A][B]

Which mechanism is consistent with this rate equation?

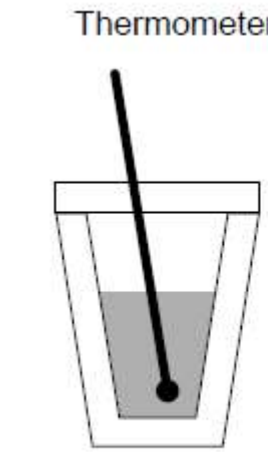
A. $2A \rightleftharpoons I$ Fast
$I + B \rightarrow P$ Slow
B. $A + B \rightleftharpoons I$ Fast
$I + A \rightarrow P$ Slow
C. $A \rightarrow I$ Slow
$I + B \rightarrow P$ Fast
D. $B \rightleftharpoons I$ Fast
$I + A \rightarrow P$ Slow

19M.1A.HL.TZ2.30

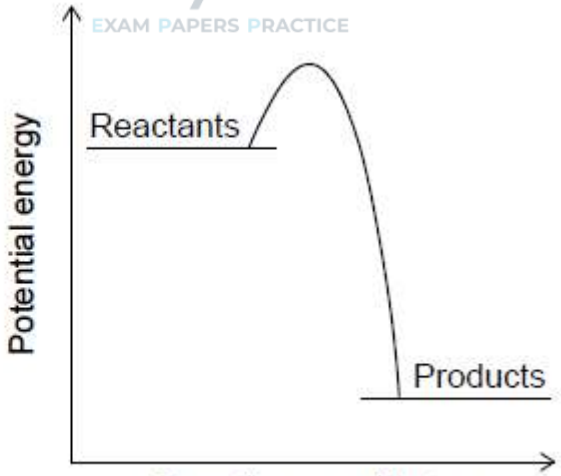
What can be deduced from the infrared (IR) spectrum of a compound? [1]
A. Number of hydrogens
B. Number of hydrogen environments
C. Bonds present
D. Molar mass

SPM.1A.HL.TZ0.20

The potential energy profile for a "coffee cup" calorimetry experiment is shown. [1]



Coffee cup calorimeter



What is the correct interpretation of this reaction?

	Temperature	Type of reaction
A.	increases	exothermic
B.	increases	endothermic
C.	decreases	exothermic
D.	decreases	endothermic

21M.1A.HL.TZ1.35

Which is most likely to hydrolyse via a S_N1 mechanism? [1]

A. $CH_3CHBrCH_2CH_3$

B. $(CH_3)_2CHBr$

C. $(CH_3)_3CBr$

D. $CH_3CH_2CH_2CH_2Br$

21M.1A.HL.TZ1.31

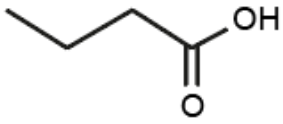
What are the products when concentrated aqueous copper (II) chloride is electrolysed using platinum electrodes?

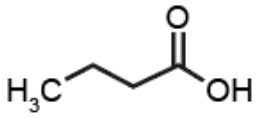
	Anode (positive electrode)	Cathode (negative electrode)
A.	$O_2(g)$	$Cu(s)$
B.	$Cl_2(g)$	$H_2(g)$
C.	$Cl_2(g)$	$Cu(s)$
D.	$O_2(g)$	$H_2(g)$

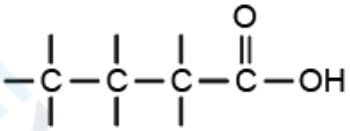
[1]

EXM.1A.HL.TZ0.2

Which of the following is the correct skeletal formula of butanoic acid? [1]

A. 

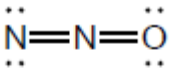
B. 

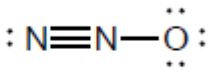
C. 

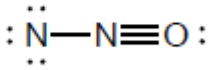
D. 

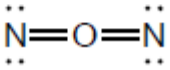
SPM.1A.HL.TZ0.9

Which is the preferred Lewis formula of nitrous oxide, N_2O, as deduced by formal charges?

A. 

B. 

C. 

D. 

[1]

19N.1A.HL.TZ0.21

Which is correct? [1]

	Units of second-order rate constant	Effect of increasing temperature on rate constant
A.	$mol\,dm^{-3}\,s^{-1}$	increases
B.	$dm^3\,mol^{-1}\,s^{-1}$	increases
C.	$mol\,dm^{-3}\,s^{-1}$	no change
D.	$dm^3\,mol^{-1}\,s^{-1}$	no change

20N.1A.HL.TZ0.23

Which statement is correct for a spontaneous reaction? [1]

	$\Delta G^{\ominus}$	K_c
A.	negative	>1
B.	negative	<1
C.	positive	<1
D.	positive	>1

21M.1A.HL.TZ2.11

What is the formula of the compound formed from Ca^{2+} and PO_4^{3-}? [1]

A. $CaPO_4$
B. $Ca_3(PO_4)_2$
C. $Ca_2(PO_4)_3$
D. $Ca(PO_4)_2$

21M.1A.HL.TZ2.12

Which atom has an expanded octet? [1]

A. C in CO_2
B. S in SCl_4
C. O in H_2O_2
D. P in PCl_3

SPM.1A.HL.TZ0.5

A gas storage tank of fixed volume V contains N molecules of an ideal gas at 300 K with a pressure of 40 kPa. $\frac{N}{4}$ molecules are removed, and the temperature is changed to 450 K.

What is the new pressure of the gas in kPa?

A. 15

B. 30
C. 45
D. 60

[1]

19M.1A.HL.TZ1.12

Which species has delocalized electrons? [1]
A. OH^-
B. H_2CO
C. CO_2
D. CO_3^{2-}

21N.1A.HL.TZ0.5

Which statement explains why the **second** ionization energy of aluminium is higher than the **first** ionization energy of magnesium?

A. Ionization energy increases along period 3.
B. 3p electrons are at a higher energy level than 3s electrons.
C. 3p electrons are further away from the nucleus than 2p electrons.
D. Both have the same number of electrons and aluminium has one more proton.

[1]

19M.1A.HL.TZ1.16

Which is correct for the reaction $H_2O(g) \rightarrow H_2O(l)$? [1]
A. Enthalpy increases and entropy increases.
B. Enthalpy decreases and entropy increases.
C. Enthalpy increases and entropy decreases.
D. Enthalpy decreases and entropy decreases.

19M.1A.HL.TZ2.35

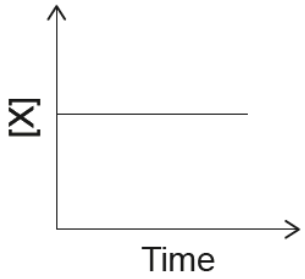
What must be present on a nucleophile? [1]
A. Negative charge
B. Lone pair of electrons
C. Positive charge
D. Symmetrical distribution of electrons

21M.1A.HL.TZ2.20

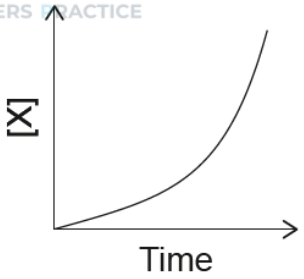
Which graph represents a second order reaction with respect to X? [1]

$X \rightarrow Y$

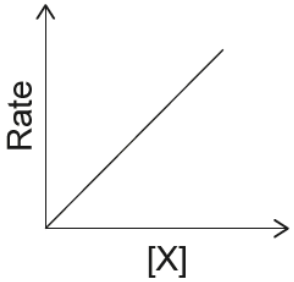
A.



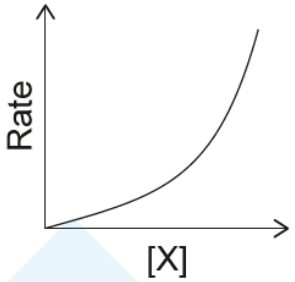
B.



C.

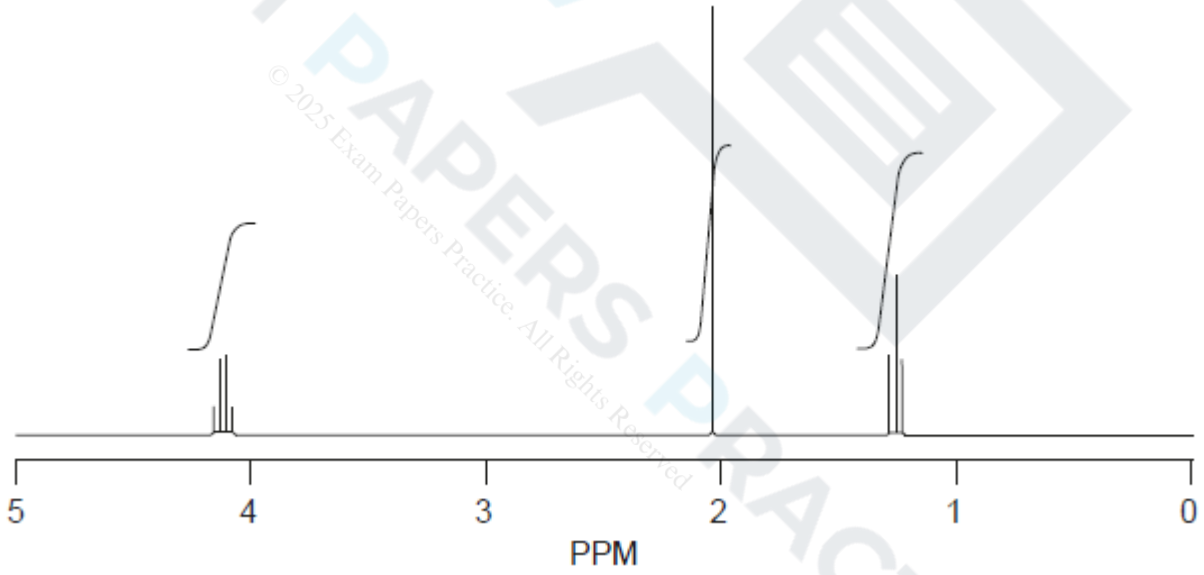


D.



21N.1A.HL.TZ0.40

Which substance has the following ^{1}H NMR spectrum? [1]

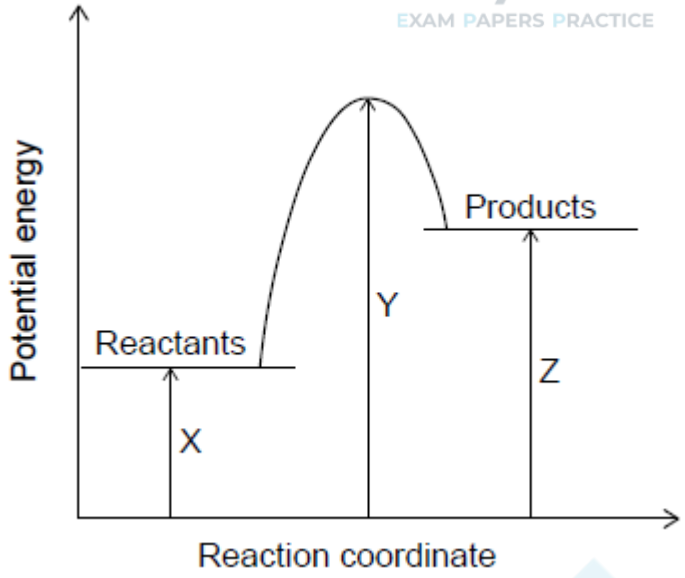


SDBS, National Institute of Advanced Science and Technology.

A. Propane
B. Propanal
C. Butanoic acid
D. Ethyl ethanoate

SPM.1A.HL.TZ0.26

The diagram shows the energy profile of a reaction. [1]

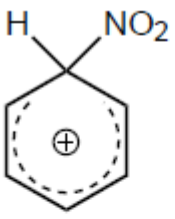


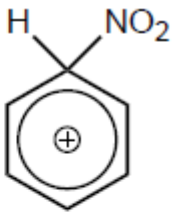
Which combination is correct?

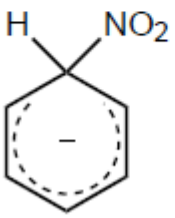
	Activation energy of forward reaction	Activation energy of reverse reaction
A.	X	Z
B.	Y – X	Y – Z
C.	Y	Y
D.	Y – X	Z – X

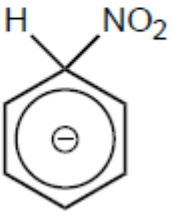
SPM.1A.HL.TZ0.40

Which illustrates the correct intermediate formed in the nitration of benzene by NO_2^+?

A. 

C. 

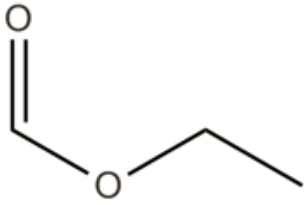
B. 

D. 

[1]

EXM.1A.HL.TZ0.3

Which is the correct structural formula of this compound? [1]



A. $OCOCH_2CH_3$
B. $HCOOC_2H_5$
C. $HCOOCH_2CH_3$
D. $OCOHC_2CH_3$

22M.1A.HL.TZ1.20

The table shows data for the hydrolysis of a halogenoalkane, RCl. [1]

[NaOH] / mol dm^{-3}	[RCl] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
0.1	0.01	5.0×10^{-7}
0.2	0.01	1.0×10^{-6}
0.2	0.02	1.9×10^{-6}

Which statements are correct?

I. The reaction is first order with respect to RCl.
II. The reaction is second order overall.
III. The reaction proceeds by an S_N2 mechanism.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

20N.1A.HL.TZ0.17

Which reaction becomes more spontaneous as temperature increases? [1]

A. $CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$
B. $N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$
C. $3CO_2\ (g) + 4H_2O\ (g) \rightarrow C_3H_8\ (g) + 5O_2\ (g)$
D. $SO_2\ (g) + H_2O_2\ (l) \rightarrow H_2SO_4\ (l)$

19M.1A.HL.TZ2.17

Which change has the greatest increase in entropy? [1]

A. CO_2 (s) → CO_2 (g)
B. CO_2 (g) → CO_2 (l)
C. CO_2 (g) → CO_2 (s)

D. $CO_2(l) \rightarrow CO_2(s)$

22N.1A.HL.TZ0.27

Which species can act both as a Lewis acid and a Lewis base? [1]

A. H_2O
B. NH_4^+
C. Cu^{2+}
D. CH_4

21M.1A.HL.TZ1.20

A reaction proceeds by the following mechanism: [1]

step 1: $A + A \rightarrow B$
step 2: $B + C \rightarrow D$

Which rate equation is consistent with this mechanism?

A. Rate = $k[B]^2[C]$
B. Rate = $k[A]^2[B][C]$
C. Rate = $k[A]^2$
D. Rate = $k[A][C]$

21N.1A.HL.TZ0.15

Which equation represents the standard enthalpy of formation of lithium oxide? [1]

A. $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$
B. $2Li(s) + \frac{1}{2}O_2(g) \rightarrow Li_2O(s)$
C. $Li(s) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}Li_2O(s)$
D. $Li(g) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}Li_2O(g)$

22M.1A.HL.TZ1.17

In which reaction does entropy decrease? [1]

A. $NaCl(s) \rightarrow NaCl(aq)$
B. $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
C. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$
D. $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

EXM.1A.HL.TZ0.4

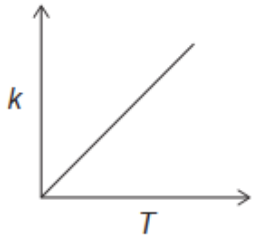
Which of the following elements yields a basic oxide when combusted? [1]

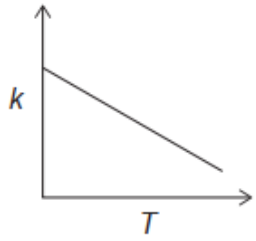
A. Au
B. P
C. Ca

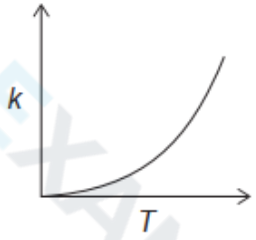
D. N

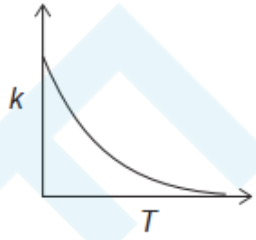
20N.1A.HL.TZ0.21

Which graph represents the relationship between the rate constant, k , and temperature, T , in kelvin?

A. 

B. 

C. 

D. 

[1]

19M.1A.HL.TZ2.36

Which compound exists as two configurational isomers? [1]
A. $CBr_2=CH_2$
B. $CH_2=CHBr$
C. $CHBr_2CH_2Br$
D. CHBr=CHBr

22N.1A.HL.TZ0.16

Which alkane has the lowest standard entropy, $S^{\ominus}$? [1]

A. $CH_4(g)$
B. $C_2H_6(g)$
C. $C_3H_8(g)$
D. $C_4H_{10}(g)$

22M.1A.HL.TZ2.40

Given equimolar concentrations, which substance would produce the strongest signal in a ^1H NMR spectrum?

A. $(CH_3)_3CH$
B. C_6H_6
C. C_8H_{18}

D. $Si(CH_3)_4$

[1]

19M.1A.HL.TZ2.25

Which of the following can be both formed from bromoethane and converted directly into ethanal?

$$CH_3CH_2Br \rightarrow \mathbf{X}$$
$$\mathbf{X} \rightarrow CH_3CHO$$

A. CH_3CH_2OH
B. CH_3OCH_3
C. CH_3COOH
D. $H_2C{=}CHBr$

[1]

22M.1A.HL.TZ1.12

For which species can resonance structures be drawn? [1]
A. HCOOH
B. $HCOO^-$
C. CH_3OH
D. H_2CO_3

19N.1A.HL.TZ0.8

What is the effect of a stronger ligand? [1]

	d–d splitting	Wavelength absorbed
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	decreases	increases

SPM.1A.HL.TZ0.16

Which d block element has the highest number of different oxidation states? [1]

A. Ti
B. Mn
C. Cu
D. Zn

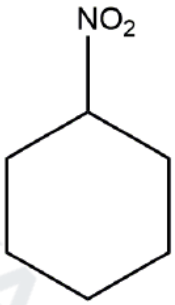
19M.1A.HL.TZ1.8

Which electrons are removed from iron (Z = 26) to form iron(II)? [1]
A. two 3d electrons
B. two 4s electrons
C. one 4s electron and one 3d electron
D. two 4p electrons

21M.1A.HL.TZ1.36

What is the product of the reaction of benzene with a mixture of concentrated nitric and sulfuric acids?

A.



C.

B.

D.

[1]

21M.1A.HL.TZ2.27

Which compound is acidic in aqueous solution? [1]
A. KBr
B. CH_3COONa
C. NH_4Cl
D. Na_2CO_3

19N.1A.HL.TZ0.27

Which can act as a Lewis acid but not a Brønsted–Lowry acid? [1]
A. BF_3
B. H_2O
C. NF_3
D. NH_3

19M.1A.HL.TZ2.12

How many sigma (σ) and pi (π) bonds are present in hydrogen cyanide, HCN? [1]

	Sigma (σ)	Pi (π)
A.	1	1
B.	2	2
C.	2	1
D.	1	3

20N.1A.HL.TZ0.27

What is the pH of an ammonia solution that has $[\mathrm{OH^-}] = 1 \times 10^{-4}\ \mathrm{mol\ dm^{-3}}$? [1]

A. 4.0
B. 8.0
C. 10.0
D. 12.0

19M.1A.HL.TZ1.23

Which is correct for a reaction with a positive change in Gibbs free energy, ΔG^{θ}? [1]

A. The formation of reactants is favoured.
B. The formation of products is favoured.
C. The reaction is at equilibrium.
D. The reaction is spontaneous.

22M.1A.HL.TZ1.14

What is the enthalpy change of the following reaction? [1]

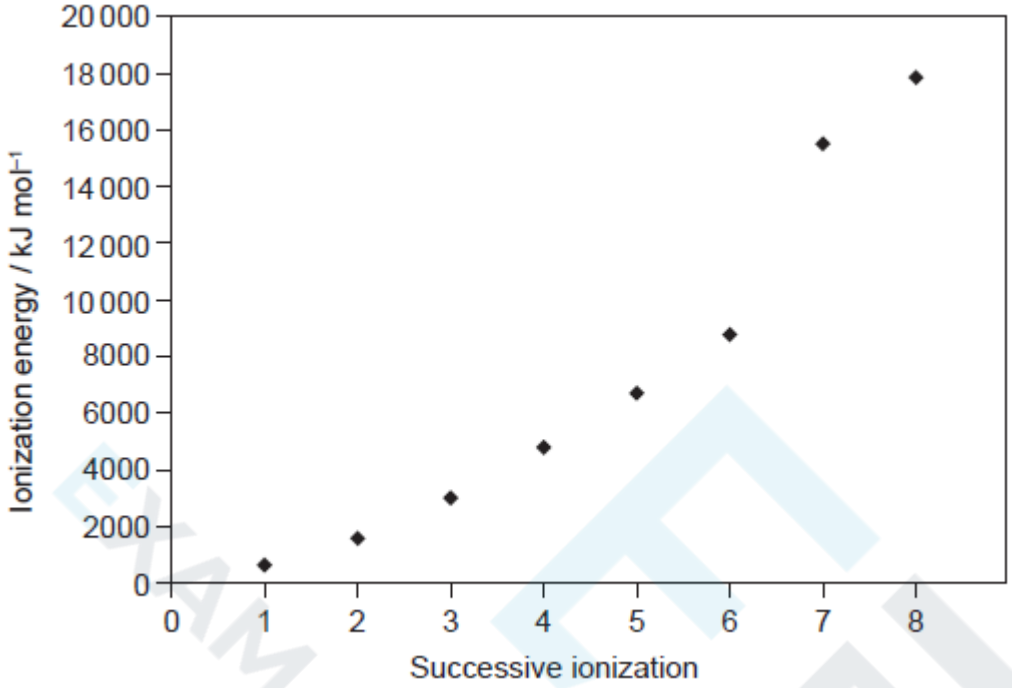
$\mathrm{CH_2CHCH_2CH_3 + HBr \rightarrow CH_3CHBrCH_2CH_3}$

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$\mathrm{CH_2CHCH_2CH_3}$	0.1
HBr	−36.3
$\mathrm{CH_3CHBrCH_2CH_3}$	−156.0

A. −119.6 kJ
B. +119.6 kJ
C. −119.8 kJ
D. +119.8 kJ

21M.1A.HL.TZ2.5

The first eight successive ionization energies for an element are shown. In which group is the element?



A. 6
B. 7
C. 8
D. 17

[1]

19M.1A.HL.TZ2.8

What is the oxidation state of the metal ion and charge of the complex ion in $[Co(NH_3)_4Cl_2]Cl$?

	Oxidation state of metal ion	Charge of complex ion
A.	+1	2+
B.	+2	1+
C.	+3	1+
D.	+3	0

[1]

20N.1A.HL.TZ0.20

What are the units of the rate constant, k , if the rate equation is $\text{Rate} = \text{kAB}^2$? [1]

A. $\text{mol dm}^{-3}\ \text{s}^{-1}$
B. $\text{dm}^3\ \text{mol}^{-1}\ \text{s}^{-1}$
C. $\text{dm}^6\ \text{mol}^{-2}\ \text{s}^{-1}$
D. $\text{dm}^9\ \text{mol}^{-3}\ \text{s}^{-1}$

20N.1A.HL.TZ0.26

Which species is a Lewis acid but **not** a Brønsted–Lowry acid? [1]

A. Cu^{2+}
B. NH_4^+
C. Cu
D. CH_3COOH

22N.1A.HL.TZ0.33

Which compound has a chiral carbon? [1]

A. Bromoethane
B. 2-bromopropane
C. 2-bromobutane
D. 3-bromopentane

21N.1A.HL.TZ0.35

Which statement is correct about configurational isomers?

A. Configurational isomers can only be interconverted by breaking and reforming bonds.
B. Configurational isomers have different molecular formulas but the same structural formulas.
C. Configurational isomers are not distinct compounds.
D. Configurational isomers always have identical physical properties.

[1]

20N.1A.HL.TZ0.37

Which molecule has an enantiomer? [1]

A. $\text{CH}_3\text{CH}_2\text{CH(OH)CH}_2\text{CH}_3$
B. $\text{CH}_2\text{(OH)CH}_2\text{CH}_2\text{CH} = \text{CH}_2$
C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH} = \text{CHBr}$
D. $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_3$

21M.1A.HL.TZ1.9

What is the overall charge, x , of the chromium (III) complex? [1]

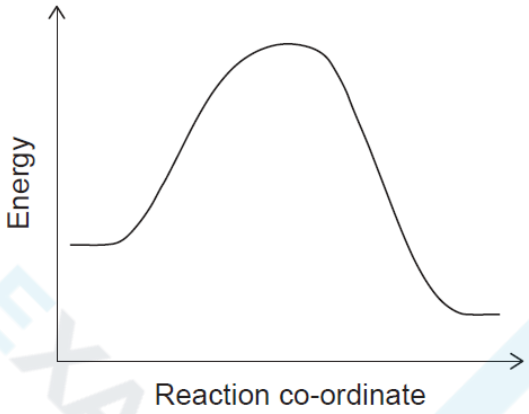
$$[\text{Cr(H}_2\text{O)}_4\text{Cl}_2]^x$$

A. 0
B. 1+
C. 2−
D. 3+

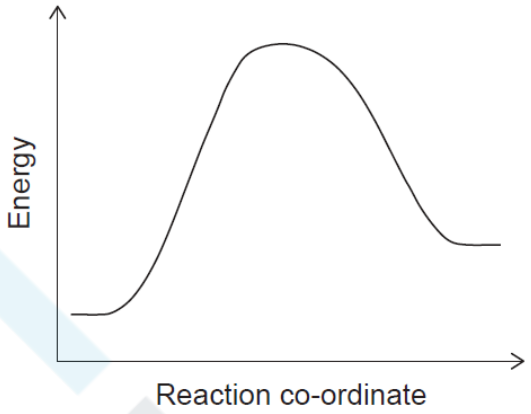
22M.1A.HL.TZ2.20

Which energy profile diagram represents an exothermic S_N1 reaction?

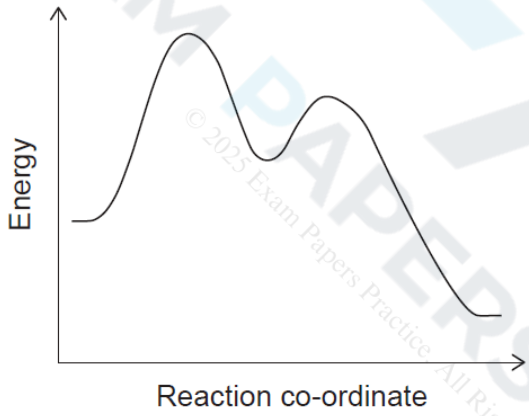
A.



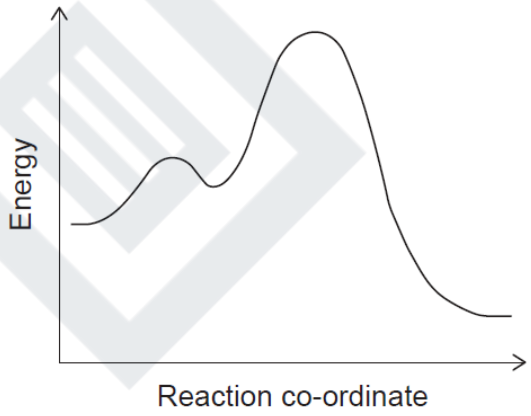
B.



C.



D.



[1]

22M.1A.HL.TZ1.27

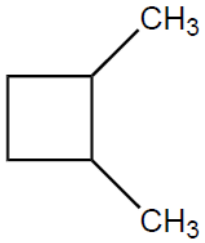
In which set are the salts arranged in order of increasing pH? [1]
A. $HCOONH_4 < KBr < NH_4Br < HCOOK$
B. $KBr < NH_4Br < HCOOK < HCOONH_4$
C. $NH_4Br < HCOONH_4 < KBr < HCOOK$
D. $HCOOK < KBr < HCOONH_4 < NH_4Br$

19M.1A.HL.TZ1.37

Which compound can exist as cis- and trans-isomers? [1]

A. $CH_2=CHCH_2CH_3$

B. $CBr_2=CF_2$

C. 

D. 

21M.1A.HL.TZ1.30

Which gives the equation and cell potential of the spontaneous reaction? [1]

	$E^{\ominus}$ / V
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.18
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80

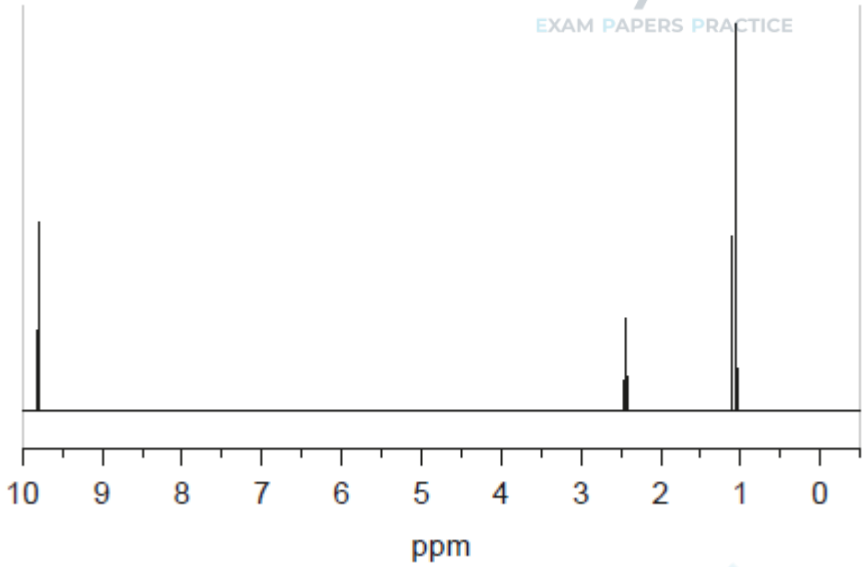
		$E^{\ominus}$ / V
A.	$Mn^{2+}(aq) + 2Ag(s) \rightarrow Mn(s) + 2Ag^+(aq)$	−1.98
B.	$Mn^{2+}(aq) + 2Ag(s) \rightarrow Mn(s) + 2Ag^+(aq)$	+0.38
C.	$Mn(s) + 2Ag^+(aq) \rightarrow Mn^{2+}(aq) + 2Ag(s)$	−0.38
D.	$Mn(s) + 2Ag^+(aq) \rightarrow Mn^{2+}(aq) + 2Ag(s)$	+1.98

19M.1A.HL.TZ2.39

What can be deduced from the infrared (IR) spectrum of a compound? [1]
A. Number of hydrogens
B. Number of hydrogen environments
C. Bonds present
D. Molar mass

22M.1A.HL.TZ1.38

Which compound produces the following ^{1}H NMR spectrum? [1]



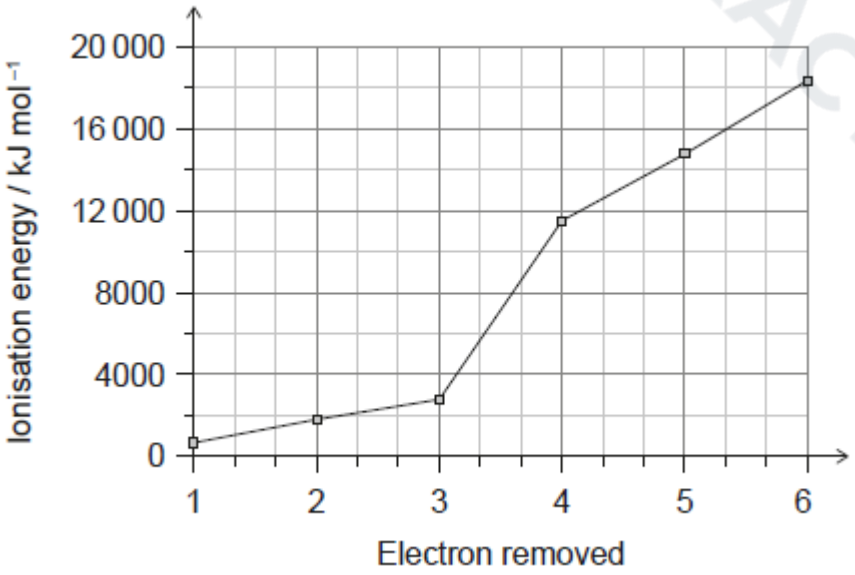
A. propanal
B. propanone
C. propane
D. methlypropane

20N.1A.HL.TZ0.35

Which is the electrophile in the nitration of benzene? [1]
A. HNO_3
B. NO_2^+
C. NO_2^-
D. NH_4^+

22M.1A.HL.TZ1.5

The graph shows the first six ionization energies of an element.



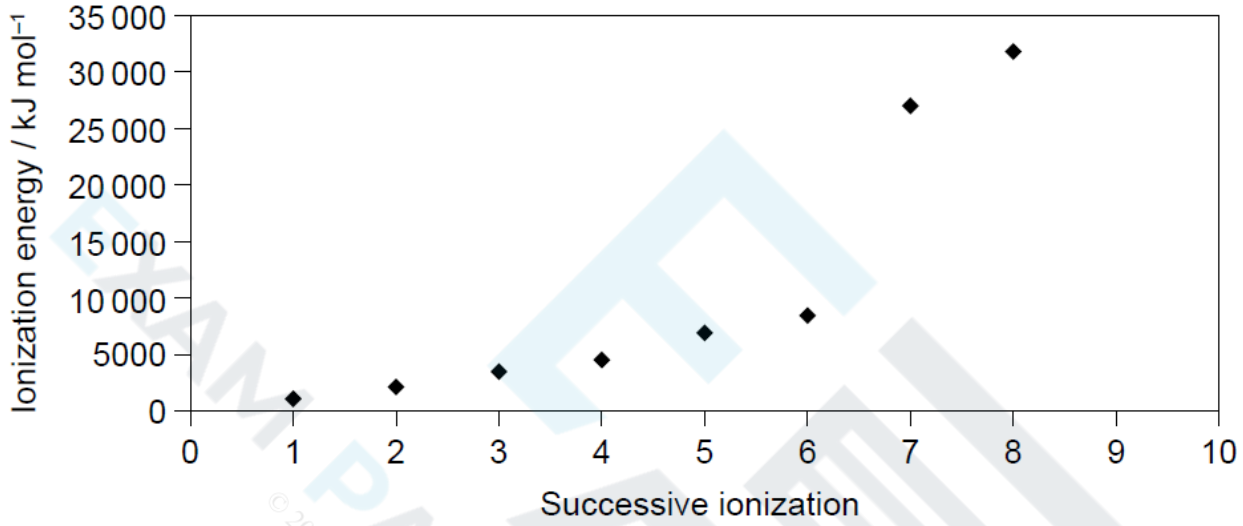
In which group is the element?
A. 13

B. 14
C. 15
D. 16

[1]

19M.1A.HL.TZ1.5

Which element is represented by the first eight successive ionization energies on the graph?

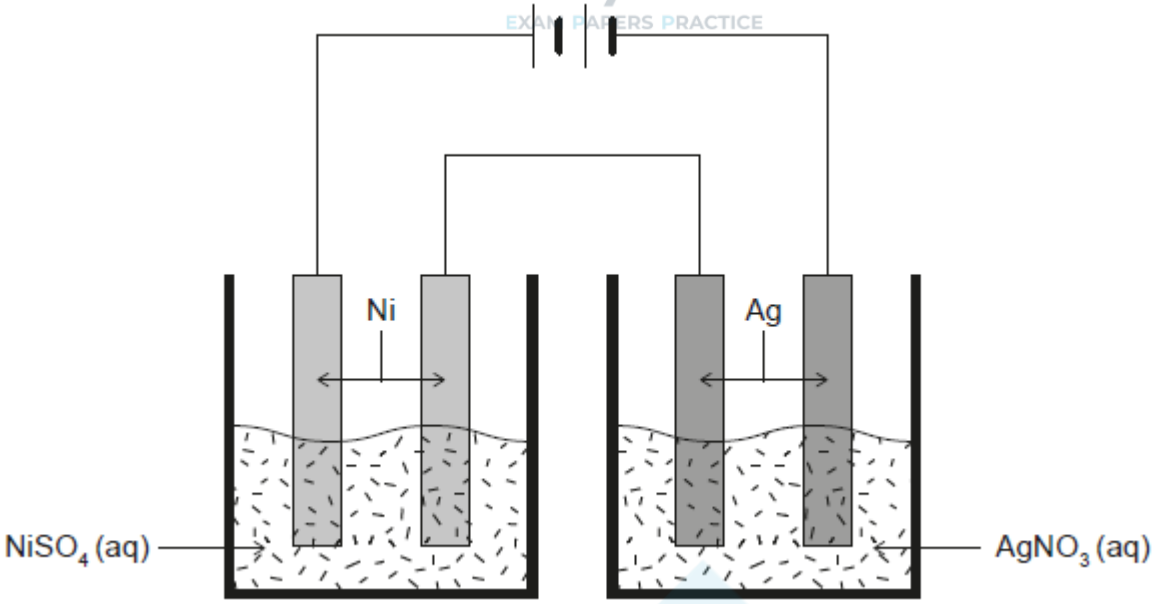


A. Mg
B. S
C. Cl
D. Ar

[1]

22M.1A.HL.TZ1.31

In the electrolysis apparatus shown, 0.59 g of Ni is deposited on the cathode of the first cell.



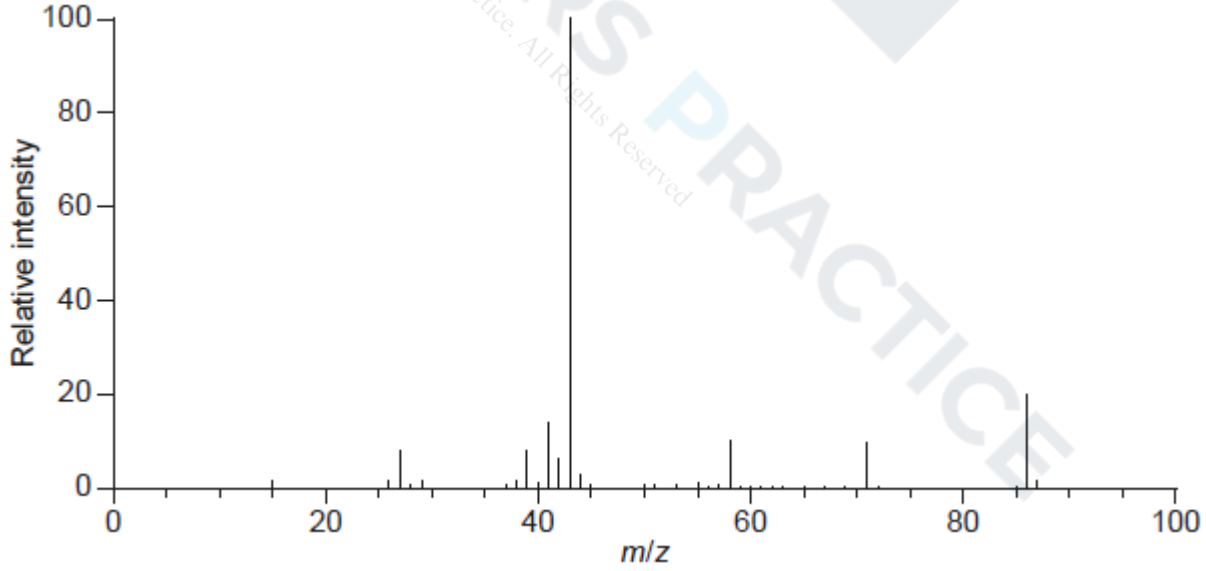
What is the mass of Ag deposited on the cathode of the second cell?

A. 0.54 g
B. 0.59 g
C. 1.08 g
D. 2.16 g

[1]

21N.1A.HL.TZ0.30

What can be deduced from the mass spectrum of $CH_3COCH_2CH_2CH_3$?



NIST Mass Spectrometry Data Center Collection (C) 2021 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved. 2-Pentanone Mass Spectrum, MS Number 291264. [graph] Available at: https://webbook.nist.gov/cgi/cbook.cgi?ID=C107879&Units=SI&Mask=200#Mass-Spec2-pentanone [Accessed 4 May 2020]. source adapted.

A. The molar mass is 43 g mol^{-1}.
B. The atoms have many isotopes.
C. The most likely bond to break is C–C between carbons 2 and 3.

D. The signal with the largest mass is due to the oxidation of the ketone in the spectrometer.

[1]

EXM.1A.HL.TZ0.7

Which of the following can act as a nucleophile? [1]

I. Benzene
II. Water
III. Bromine

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

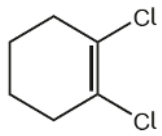
21M.1A.HL.TZ2.35

Which compound shows *cis-trans* isomerism? [1]

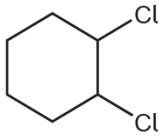
A. $CH_3CH{=}CCl_2$

B. $CCl_2{=}CH_2$

C.



D.



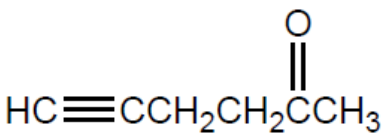
21N.1A.HL.TZ0.8

Which complex ion contains a central ion with an oxidation state of +3? [1]

A. $[PtCl_6]^{2-}$
B. $[Cu(H_2O)_4(OH)_2]$
C. $[Ni(NH_3)_4(H_2O)_2]^{2+}$
D. $[Co(NH_3)_4Cl_2]^{+}$

19M.1A.HL.TZ1.13

How many carbon atoms are sp^3, sp^2 and sp hybridized in the molecule? [1]



	sp^3	sp^2	sp
A.	3	1	2
B.	2	1	3
C.	3	2	1
D.	3	2	2

SPM.1A.HL.TZ0.8

What is the molecular geometry of the central atom in SF_4Cl_2? [1]

A. linear
B. tetrahedral
C. hexagonal
D. octahedral

22N.1A.HL.TZ0.6

Which best explains why complexes of d-block elements are coloured? [1]

A. Light is absorbed when electrons are promoted between d orbitals.
B. Light is emitted when electrons are promoted between d orbitals.
C. Light is absorbed when electrons return to lower energy d orbitals.
D. Light is emitted when electrons return to lower energy d orbitals.

19M.1A.HL.TZ2.23

Iodine and bromine gases were mixed and allowed to reach equilibrium. [1]

$$I_2(g) + Br_2(g) \rightleftharpoons 2IBr(g)$$

	$[I_2]$	$[Br_2]$	[IBr]
Initial concentration	0.20	0.20	0.00
Equilibrium concentration	0.10	0.10	x

What is the value of the equilibrium constant?
A. 0.05
B. 1
C. 4
D. 10

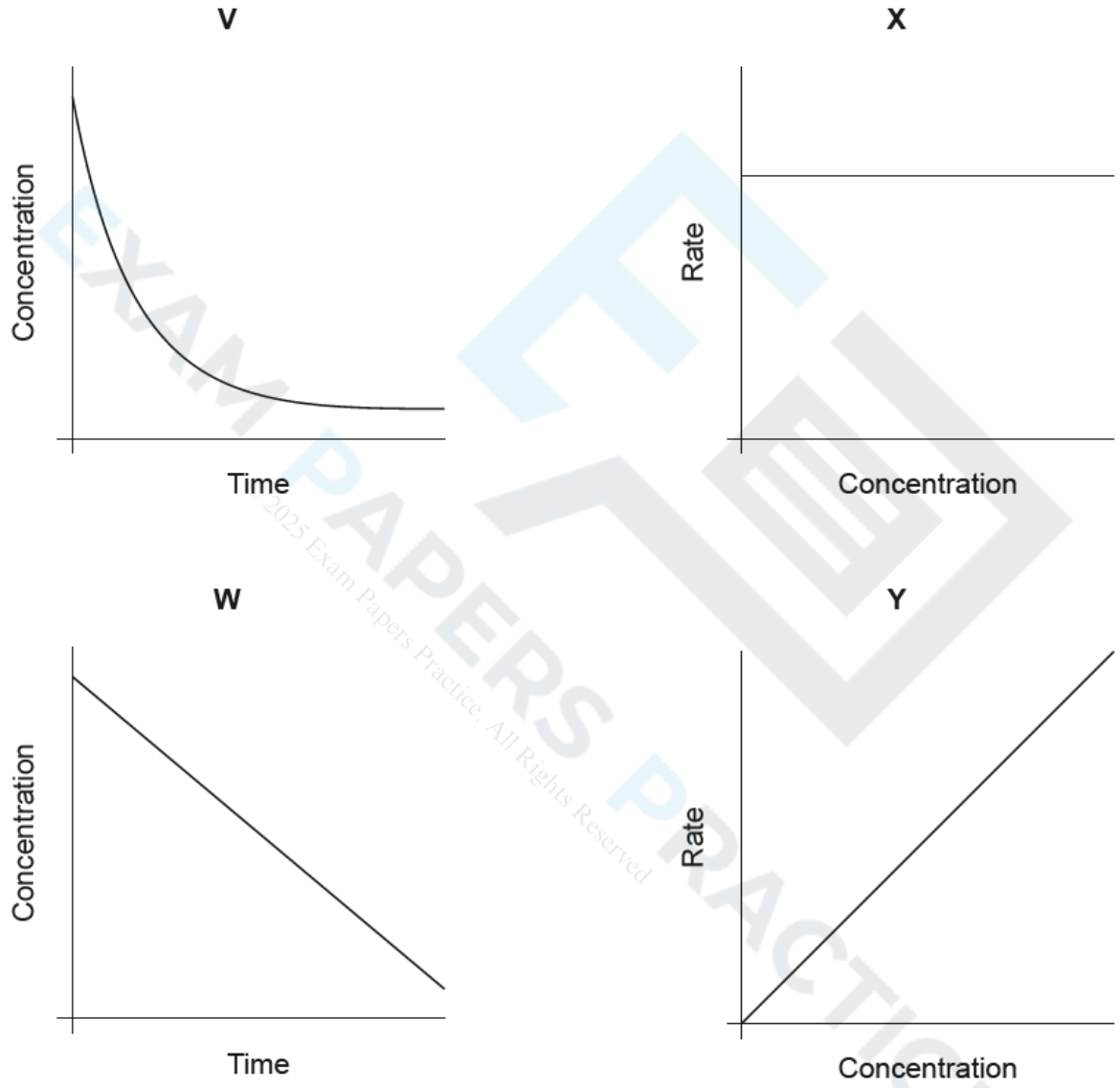
21M.1A.HL.TZ1.13

In which series are all carbon atoms sp^2 hybridized? [1]

A. $C_2H_2H_2CO$ HCOOH
B. $C_2H_4H_2CO$ HCOOH
C. C_2H_2CO HCN
D. $C_2H_6CH_3OH$ CH_3OCH_3

21M.1A.HL.TZ1.21

Which graphs show a first order reaction? [1]



A. V and X
B. V and Y
C. W and X
D. W and Y

19M.1A.HL.TZ1.10

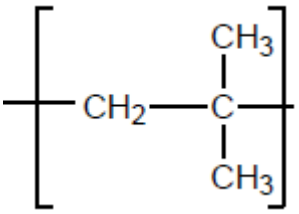
Which species does **not** have resonance structures? [1]

A. C_6H_6
B. NH_4^+
C. CO_3^{2-}

D. O_3

SPM.1A.HL.TZ0.12

The structure shows the repeating unit of a polymer found in some plastics. [1]

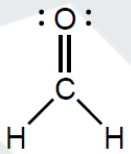


Which monomer is used to form this plastic?

A. $H_2C=C(CH_3)_2$
B. $CH_3CH(CH_3)_2$
C. $(H_3C)_2C=C(CH_3)_2$
D. $(H_3C)_2C=CHCH(CH_3)_2$

19M.1A.HL.TZ2.13

What is the hybridization of carbon and oxygen in methanol? [1]



	Hybridization of C	Hybridization of O
A.	sp^2	sp^2
B.	sp^2	sp
C.	sp	sp^2
D.	sp^3	sp^3

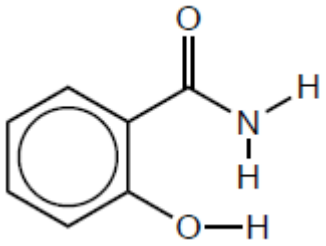
22M.1A.HL.TZ1.8

Why is hydrated copper (II) sulfate blue?
A. Blue light is emitted when electrons return to lower d-orbitals.
B. Light complimentary to blue is absorbed when electrons return to lower d-orbitals.
C. Blue light is emitted when electrons are promoted between d-orbitals.
D. Light complimentary to blue is absorbed when electrons are promoted between d-orbitals.

[1]

SPM.1A.HL.TZ0.10

Which pair of statements about electrons in this molecule is correct? [1]



	Number of non-bonding pairs of electrons	Number of electrons in π bonds
A.	3	6
B.	3	8
C.	5	6
D.	5	8

21N.1A.HL.TZ0.17

In which of the following situations is the forward reaction spontaneous? [1]

A. The equilibrium constant is greater than one under standard conditions.
B. The cell potential is negative.
C. The Gibbs free energy change of the reverse reaction is negative.
D. The entropy change of the universe for the forward reaction is negative.

22N.1A.HL.TZ0.21

The activation energy of a reaction can be obtained from the rate constant, k, and the absolute temperature, T. Which graph of these quantities produces a straight line?

A. k against T
B. k against $\frac{1}{T}$
C. ln k against T
D. ln k against $\frac{1}{T}$

[1]

SPM.1A.HL.TZ0.31

Which reaction would be expected to have the largest Arrhenius (pre-exponential) factor, A, at constant temperature?

A. $H(g) + I(g) \rightarrow HI(g)$
B. $H_2(g) + I_2(g) \rightarrow 2HI(g)$
C. $2HCl(g) \rightarrow H_2(g) + Cl_2(g)$

D. $H_2 + C_2H_4 \rightarrow C_2H_6$

[1]

22N.1A.HL.TZ0.22

For the reaction $I_2(g) + 3Cl_2(g) \rightleftharpoons 2ICl_3(g)$ at a certain temperature, the equilibrium concentrations are (in mol dm^{-3}):

$$[I_2] = 0.20, [Cl_2] = 0.20, [ICl_3] = 2.0$$

What is the value of K_c?

A. 0.25
B. 50
C. 2500
D. 5000

[1]

22M.1A.HL.TZ1.18

$\frac{1}{2}Cl_2(g) + \frac{1}{2}I_2(g) \rightleftharpoons ICl(g)$ $K_c = 454$ [1]

What is the K_c value for the reaction below?

$$2ICl(g) \rightleftharpoons Cl_2(g) + I_2(g)$$

A. 2×454
B. $\frac{1}{2 \times 454}$
C. 454^2
D. $\frac{1}{454^2}$

19N.1A.HL.TZ0.22

What is the intercept on the y-axis when a graph of ln k is plotted against $\frac{1}{T}$ on the x-axis?

$$\ln k = -\frac{E_a}{RT} + \ln A$$

A. ln A
B. $-\frac{E_a}{R}$
C. $-\frac{R}{E_a}$
D. E_a

[1]

22N.1A.HL.TZ0.23

Which of these changes would shift the equilibrium to the right? [1]

$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$

I. Addition of 0.01 M HCl
II. Addition of concentrated HCl
III. Evaporation of water

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

SPM.1A.HL.TZ0.7

In which group of ions and molecules are electrons delocalized in all species? [1]

A. CH_3COOH, O_3, C_{60}
B. CH_3COO^-, NO_2^-, C(graphite)
C. C_2H_2, $(COOH)_2$, C(diamond)
D. C_2H_4, NO_2^+, SiO_2

21N.1A.HL.TZ0.37

Which attacking species is matched with its mechanism of reaction? [1]

	Attacking species	Type of mechanism
A.	OH^-	Electrophilic substitution
B.	Cl^+	Nucleophilic addition
C.	NH_4^+	Nucleophilic addition
D.	NO_2^+	Electrophilic substitution

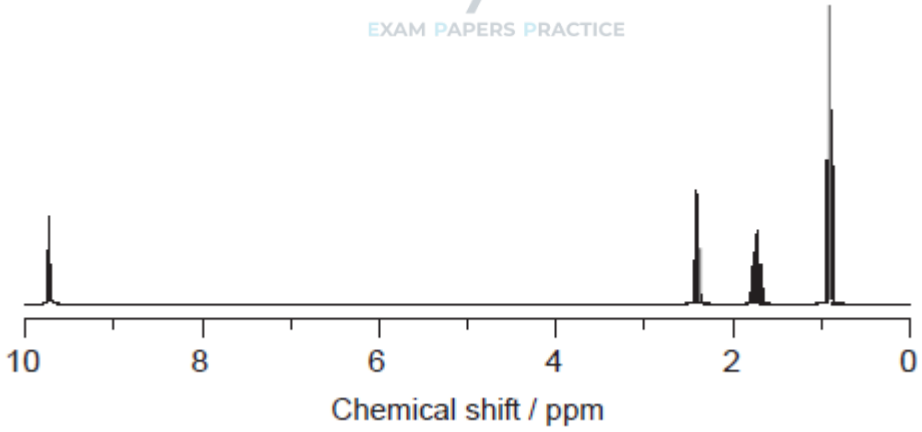
20N.1A.HL.TZ0.5

Which element is in group 13? [1]

	Ionization energy / kJ mol^{-1}			
	1st	2nd	3rd	4th
A.	789	1580	3230	4360
B.	578	1820	2750	11 600
C.	738	1450	7730	10 500
D.	496	4560	6910	9540

20N.1A.HL.TZ0.40

Which compound with the molecular formula C_4H_8O has this high resolution H_1 NMR ?



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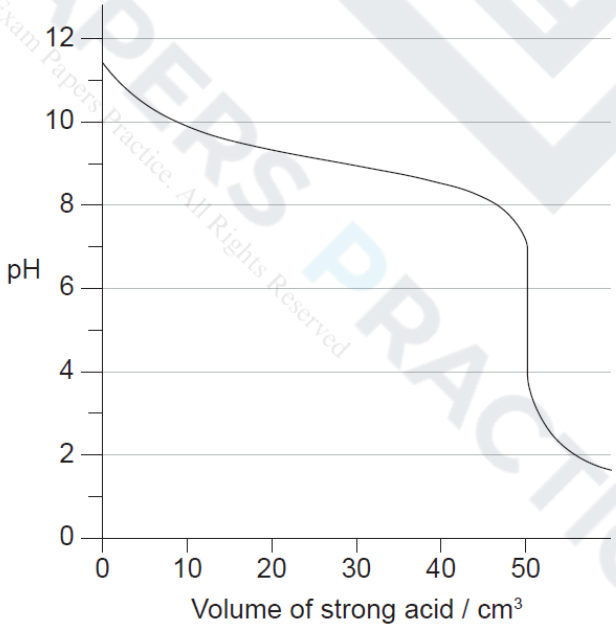
A. but-3-en-2-ol, $CH_2 = CHCH(OH)CH_3$
B. butanal, $CH_3CH_2CH_2CHO$
C. butanone, $CH_3COCH_2CH_3$
D. but-3-en-1-ol, $CH_2 = CHCH_2CH_2OH$

[1]

22M.1A.HL.TZ2.26

A weak base is titrated with a strong acid. Which value of p K_b can be estimated from this titration curve?

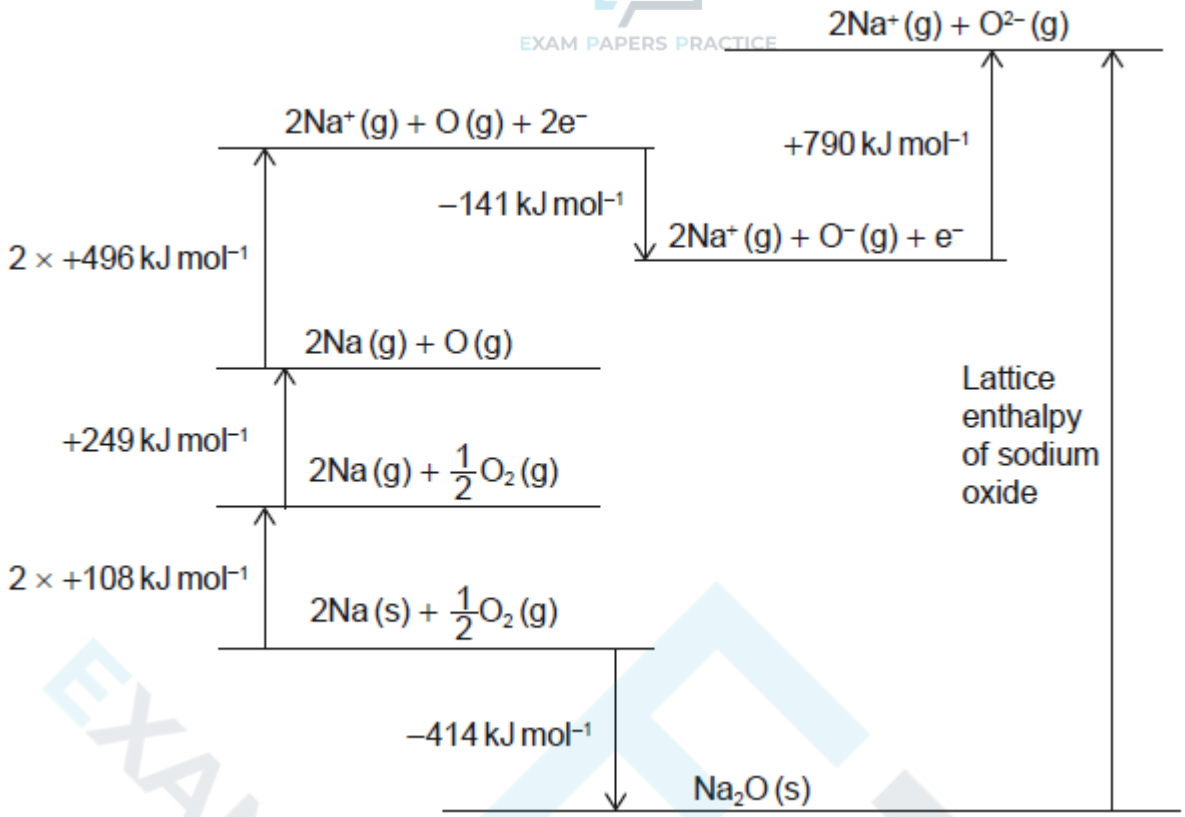


A. 11.3
B. 9.2
C. 4.8
D. 1.8

[1]

21N.1A.HL.TZ0.16

Consider the Born–Haber cycle for the formation of sodium oxide: [1]



What is the lattice enthalpy, in kJ mol^{-1}, of sodium oxide?

A. 414 + 2(108) + 249 + 2(496) − 141 + 790
B. 414 + 2(108) + 249 + 2(496) + 141 + 790
C. −414 + 2(108) + 249 + 2(496) − 141 + 790
D. −414 − 2(108) − 249 − 2(496) + 141 − 790

19M.1A.HL.TZ2.6

How is colour produced in transition metal complexes? [1]
A. Light is absorbed when electrons are promoted between split d-orbitals.
B. Light is emitted when electrons fall between split d-orbitals.
C. Light is absorbed when electrons escape from the complex.
D. Light is emitted when the complex returns to ground state.

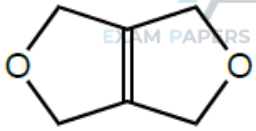
19N.1A.HL.TZ0.36

In which compound is the halogen substituted the most rapidly by aqueous hydroxide ions?
A. $(CH_3)_3CCl$
B. $(CH_3)_3CI$
C. $CH_3CH_2CH_2CH_2Cl$
D. $CH_3CH_2CH_2CH_2I$

[1]

22M.1A.HL.TZ2.28

How many signals are observed in the ^1H NMR spectrum of this compound? [1]



A. 1
B. 2
C. 3
D. 4

19M.1A.HL.TZ2.11

Which species has a square planar molecular geometry? [1]
A. SF_4
B. XeF_4
C. CF_4
D. PF_4^+

22M.1A.HL.TZ2.15

What are the signs of ΔH and ΔS for a reaction that is non-spontaneous at low temperatures but spontaneous at high temperatures?

	ΔH	ΔS
A.	–	–
B.	–	+
C.	+	–
D.	+	+

[1]

20N.1A.HL.TZ0.31

Which statement is correct when a zinc spoon is electroplated with silver? [1]
A. The cathode (negative electrode) is made of silver.
B. The anode (positive electrode) is the zinc spoon.
C. The anode (positive electrode) is made of silver.
D. The electrolyte is zinc sulfate solution.

19M.1A.HL.TZ2.31

What are the products when concentrated KBr (aq) is electrolyzed? [1]

	Anode (positive electrode)	Cathode (negative electrode)
A.	O_2	K
B.	O_2	H_2
C.	Br_2	K
D.	Br_2	H_2

20N.1A.HL.TZ0.11

Which combination correctly describes the geometry of BrF_4^- ? [1]

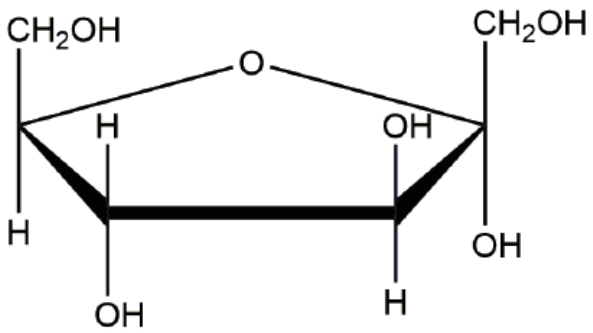
	Electron domain geometry around Br	Molecular geometry around Br
A.	Octahedral	Tetrahedral
B.	Tetrahedral	Square planar
C.	Octahedral	Square planar
D.	Tetrahedral	Tetrahedral

19M.1A.HL.TZ1.40

Which can be identified using infrared (IR) spectroscopy? [1]
A. functional groups
B. molar mass
C. 3-D configuration
D. bond angle

21M.1A.HL.TZ1.37

How many chiral centres are there in the following molecule? [1]



A. 2
B. 3
C. 4
D. 6

SPM.1A.HL.TZ0.39

Which statement is correct when 2-chloro-2-methylpentane reacts with water to form 2-methylpentan-2-ol?

A. Water acts as a nucleophile and attacks the chlorine atom.
B. The reaction occurs in a single step.
C. A carbocation intermediate is formed.
D. Homolytic bond fission occurs.

[1]

19N.1A.HL.TZ0.5

A.


B.


C.


D.


Which shows the first ionization energies of successive elements across period 2, from left to right?

[1]

SPM.1A.HL.TZ0.6

What is the formula of the compound formed between magnesium ions and hydrogencarbonate ions?

A. $MgHCO_3$
B. $Mg(HCO_3)_2$
C. $Mg(HCO_3)_3$
D. $Mg_3(HCO_3)_2$

[1]

SPM.1A.HL.TZ0.21

What is the enthalpy change for the reaction in kJ mol^{-1}? [1]

$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$$

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g) \quad \Delta H = -566 \text{ kJ mol}^{-1}$$

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H = -572 \text{ kJ mol}^{-1}$$

$$H_2O(g) \rightarrow H_2O(l) \quad \Delta H = -44 \text{ kJ mol}^{-1}$$

A. - 1182
B. - 899
C. - 41
D. + 41

SPM.1A.HL.TZ0.27

What is the main reason for an increase in rate of reaction when the temperature is raised?

A. A greater proportion of collisions are successful.
B. Particles collide more frequently.
C. The bonds in the reactants are weakened.
D. The activation energy of the reaction decreases.

[1]

19N.1A.HL.TZ0.17

Which reaction has the greatest increase in entropy of the system? [1]

A. $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
B. $(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + N_2(g) + 4H_2O(g)$
C. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
D. $I_2(g) \rightarrow I_2(s)$

21M.1A.HL.TZ1.26

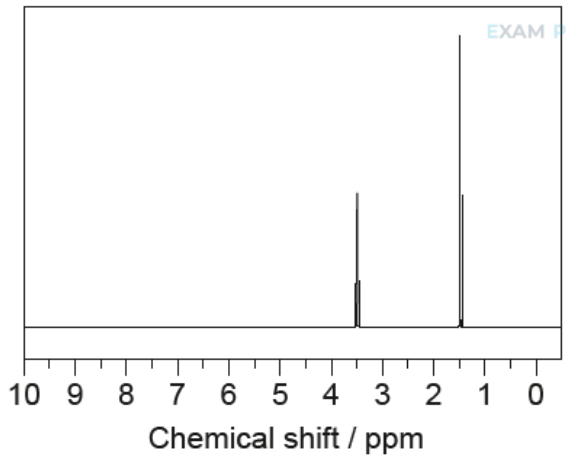
Which is a Lewis acid, but not a Brønsted-Lowry acid? [1]

A. BF_3
B. H_3O^+
C. NH_3
D. Cl^-

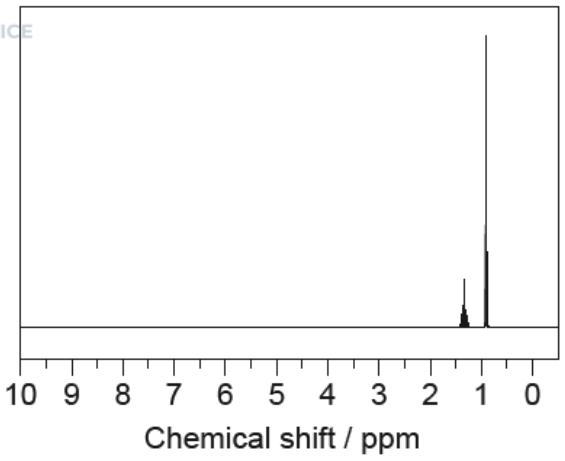
19N.1A.HL.TZ0.40

Which is the ^1H NMR spectrum of tetramethylsilane, TMS, $(CH_3)_4Si$?

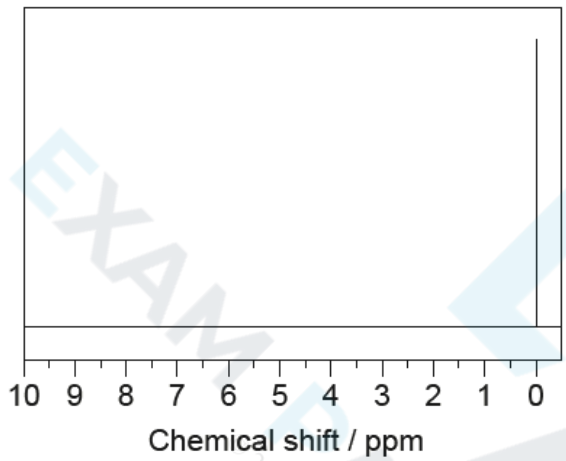
A.



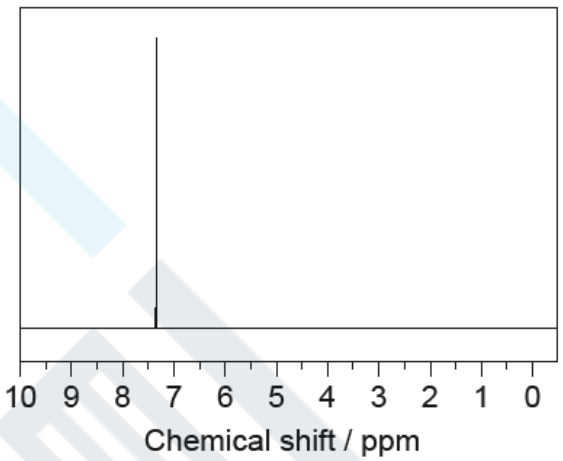
B.



C.



D.



[Source: ISDBS, National Institute of Advanced Industrial Science and Technology. Used with permission.]

[1]

SPM.1A.HL.TZ0.14

Which molecule has a carbonyl functional group? [1]

A. CH_3OCH_3
B. CH_3COCH_3
C. CH_3CH_2OH
D. $CH_3CH_2NH_2$

19N.1A.HL.TZ0.24

Which corresponds to a system at equilibrium? [1]

	Entropy	Gibbs free energy
A.	maximum	maximum
B.	maximum	minimum
C.	minimum	maximum
D.	minimum	minimum

21M.1A.HL.TZ2.17

Which change results in the largest negative value of ΔS ? [1]

A. $C_2H_5OH(l) + SOCl_2(l) \rightarrow C_2H_5Cl(l) + SO_2(g) + HCl(g)$

B. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

C. $H_2O(l) \rightarrow H_2O(s)$

D. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

SPM.1A.HL.TZ0.4

A container holds 30 g of argon and 60 g of neon.

What is the ratio of number of atoms of argon to number of atoms of neon in the container?

A. 0.25

B. 0.50

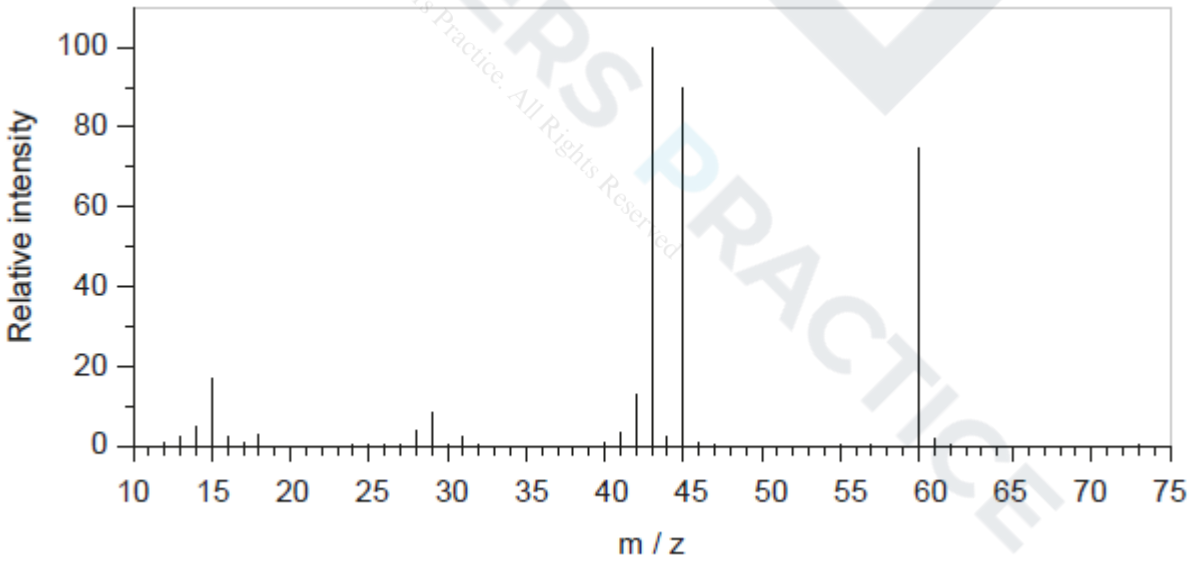
C. 2.0

D. 4.0

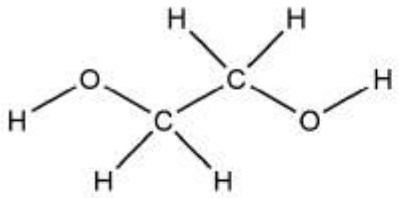
[1]

22M.1A.HL.TZ1.29

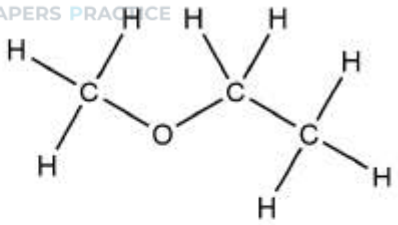
Which compound produces this mass spectrum? [1]



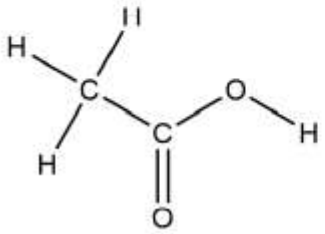
A.



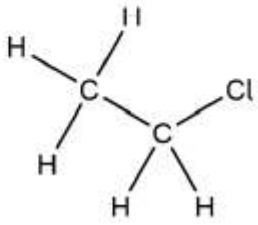
B.



C.



D.



21M.1A.HL.TZ2.28

Which spectra would show the difference between propan-2-ol, $CH_3CH(OH)CH_3$, and propanal, CH_3CH_2CHO?

I. mass
II. infrared
III. ^1H NMR

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

[1]

EXM.1A.HL.TZ0.5

Which is the product when but-1-yne reacts with excess hydrogen gas? [1]

A. But-1-ene
B. Butane
C. But-2-ene
D. No reaction

21N.1A.HL.TZ0.22

A reversible reaction has a reaction quotient, Q, of 4.5 and equilibrium constant, K_c, of 6.2.

$$2A(g) \rightleftharpoons A_2(g)$$

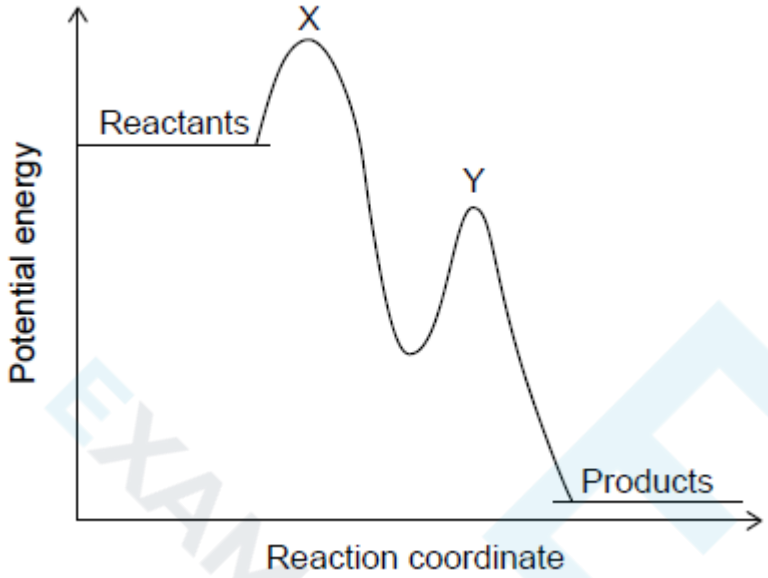
Which statement describes the reaction at this time?

A. The system has reached equilibrium.
B. The rate of the forward reaction is greater than the rate of the reverse reaction.
C. The concentration of reactant is greater than the concentration of product.
D. At equilibrium, the concentration of reactant is greater than the concentration of product.

[1]

SPM.1A.HL.TZ0.29

Which statement is correct about points X and Y on the energy profile diagram? [1]



A. X is a transition state and Y is an intermediate.
B. X is an intermediate and Y is a transition state.
C. X and Y are transition states.
D. X and Y are intermediates.

EXM.1A.HL.TZ0.8

Which is correct when benzene undergoes electrophilic substitution by chlorine, Cl_2, in presence of the catalyst, Cl_3Al?

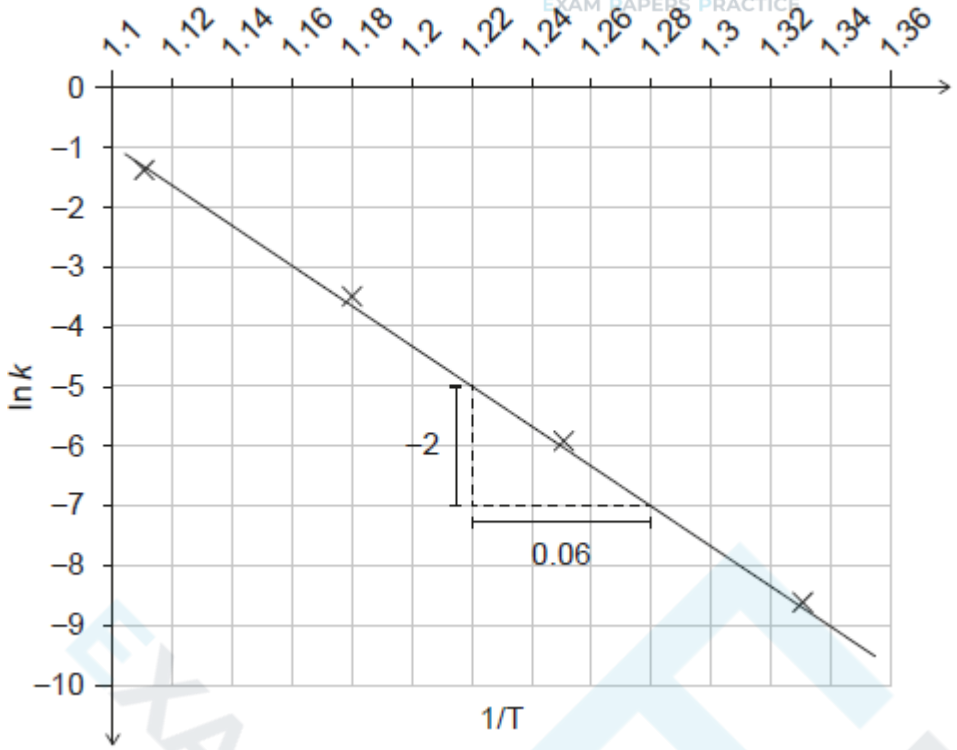
A. $C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$
B. $C_6H_6 + Cl_2 \rightarrow C_6H_4Cl_2 + H_2$
C. $C_6H_6 + Cl_2 \rightarrow C_6H_6Cl_2$
D. $C_6H_6 + Cl_2 \rightarrow C_6H_6Cl + Cl^-$

[1]

22M.1A.HL.TZ1.21

What is the activation energy according to the following plot of the linear form of the Arrhenius equation?

Arrhenius equation: $k = Ae^{\frac{-Ea}{RT}}$.



A. $E_a = \frac{2 \times 8.31}{0.06}$

B. $E_a = \frac{-2 \times 8.31}{0.06}$

C. $E_a = e^{\frac{2 \times 8.31}{0.06}}$

D. $E_a = e^{\frac{-2 \times 8.31}{0.06}}$

[1]

21N.1A.HL.TZ0.26

What is a possible value of pH at the equivalence point in the titration of a strong acid with a weak base?

A. 5
B. 7
C. 9
D. 11

[1]

19N.1A.HL.TZ0.38

Which can show optical activity? [1]

A. CHBrCHCl
B. $CH_3CH_2CHBrCH_2CH_3$
C. $(CH_3)_2CBrCl$
D. $CH_3CH_2CH(CH_3)Br$

SPM.1A.HL.TZ0.32

Which reactions involve the transfer of a proton? [1]

I. $2HCl\,(aq) + Mg\,(s) \rightarrow MgCl_2\,(aq) + H_2\,(g)$
II. $2HCl\,(aq) + MgO\,(s) \rightarrow MgCl_2\,(aq) + H_2O\,(l)$
III. $2HCl\,(aq) + MgCO_3\,(s) \rightarrow MgCl_2\,(aq) + H_2O\,(l) + CO_2\,(g)$

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

21M.1A.HL.TZ1.12

Which contain delocalised electrons? [1]

I. C_6H_5OH
II. CH_3COO^-
III. CO_3^{2-}

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

SPM.1A.HL.TZ0.36

Which statements explain the following reactions occurring in the upper atmosphere?

	Chlorofluorocarbon (CFC) compounds break down to produce chlorine radicals but usually not fluorine radicals.	A single chlorine radical breaks down many ozone, O_3, molecules.
A.	C–Cl bond is stronger than C–F bond	chain propagation steps produce more radicals
B.	C–F bond is stronger than C–Cl bond	chain termination steps cause chlorine radicals to reform chlorine molecules
C.	C–Cl bond is stronger than C–F bond	chain termination steps cause chlorine radicals to reform chlorine molecules
D.	C–F bond is stronger than C–Cl bond	chain propagation steps produce more radicals

[1]

22N.1A.HL.TZ0.26

Which solutions will form a buffer when mixed? [1]

A. 50 cm^3 of 1.0 mol dm^{-3} HCl and 50 cm^3 of 1.0 mol dm^{-3} NaOH
B. 50 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 50 cm^3 of 1.0 mol dm^{-3} NaOH
C. 50 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 100 cm^3 of 1.0 mol dm^{-3} NaOH
D. 100 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 50 cm^3 of 1.0 mol dm^{-3} NaOH

SPM.1A.HL.TZ0.11

What is the explanation for the malleability of metals? [1]

A. The bonds are strong.
B. The bonds are weak.
C. The bonds involve free electrons.
D. The bonds do not have a specific direction.

21N.1A.HL.TZ0.13

What is the hybridization of nitrogen and chlorine in NCl_3? [1]

	N	Cl
A.	sp^2	sp^2
B.	sp^2	sp^3
C.	sp^3	sp^2
D.	sp^3	sp^3

SPM.1A.HL.TZ0.35

In a redox titration, manganate(VII) ions are reduced to manganese(II) ions and iron(II) ions are oxidized to iron(III) ions.

MnO_4^- (aq) reduced to Mn^{2+} (aq)
Fe^{2+} (aq) oxidized to Fe^{3+} (aq)

What volume, in cm^3, of 0.1 mol dm^{-3} MnO_4^- (aq) is required to reach the equivalence point in the titration of 20.00 cm^3 of 0.1 mol dm^{-3} Fe^{2+} (aq)?

A. 2.00
B. 4.00
C. 20.00
D. 100.00

[1]

22M.1A.HL.TZ1.13

What are the electron domain and molecular geometries of the XeF_4 molecule? [1]

	Electron domain geometry	Molecular geometry
A.	tetrahedral	planar
B.	tetrahedral	tetrahedral
C.	octahedral	planar
D.	octahedral	tetrahedral

EXM.1A.HL.TZ0.1

Which of the following is most likely to be a transition metal? [1]

	Melting point	Electrical conductivity	Ductility
A.	High	Good	Low
B.	High	Poor	Low
C.	High	Good	High
D.	Low	Good	High

21N.1A.HL.TZ0.31

Which aqueous solutions produce oxygen gas during electrolysis? [1]

I. Dilute $CuCl_2(aq)$ with inert electrodes
II. Dilute $FeSO_4(aq)$ with inert electrodes
III. Dilute $CuCl_2(aq)$ with copper electrodes

The standard electrode potentials are provided in the table:

Half-equation	$E^\ominus$ / V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.45
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O(l)$	+1.23
$\frac{1}{2}Cl_2(g) + e^- \rightleftharpoons Cl^-(aq)$	+1.36

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

SPM.1A.HL.TZ0.22

Which is a renewable energy source? [1]

A. natural gas
B. uranium
C. coal
D. wood

22M.1A.HL.TZ1.35

What are the type of reaction and role of the nitronium ion, NO_2^+, in the following reaction?

$$C_6H_6 + NO_2^+ \rightarrow C_6H_5NO_2 + H^+$$

	Type of reaction	Role of NO_2^+
A.	substitution	electrophile
B.	addition	electrophile
C.	substitution	nucleophile
D.	addition	nucleophile

[1]

SPM.1A.HL.TZ0.37

Which term cannot characterize ammonia, NH_3? [1]

A. Lewis acid
B. Brønsted–Lowry acid
C. ligand
D. nucleophile

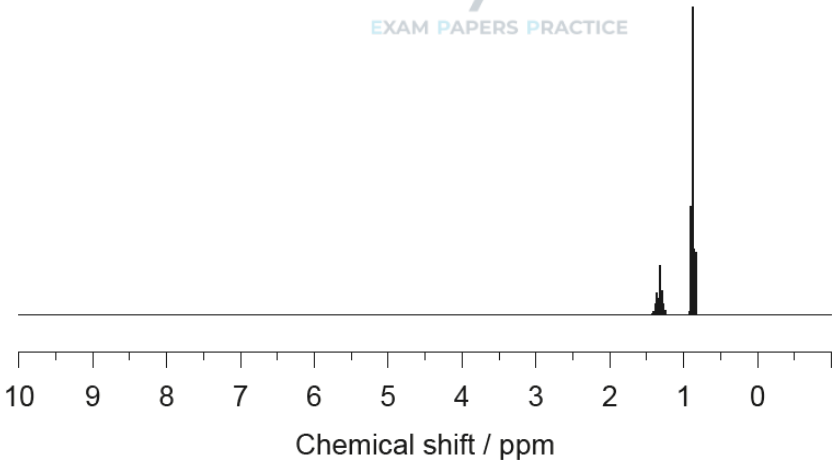
SPM.1A.HL.TZ0.38

Which ion is a better leaving group in nucleophilic substitutions? [1]

A. bromide ion
B. chloride ion
C. fluoride ion
D. iodide ion

21M.1A.HL.TZ1.40

Which compound produces the following ^1H NMR spectrum? [1]



SDBS, National Institute of Advanced Industrial Science and Technology (AIST).

A. Propane
B. Propanone
C. Propanal
D. 2,2-dimethylpropane

SPM.1A.HL.TZ0.30

The equation for the reaction between two gases, A and B, is:

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

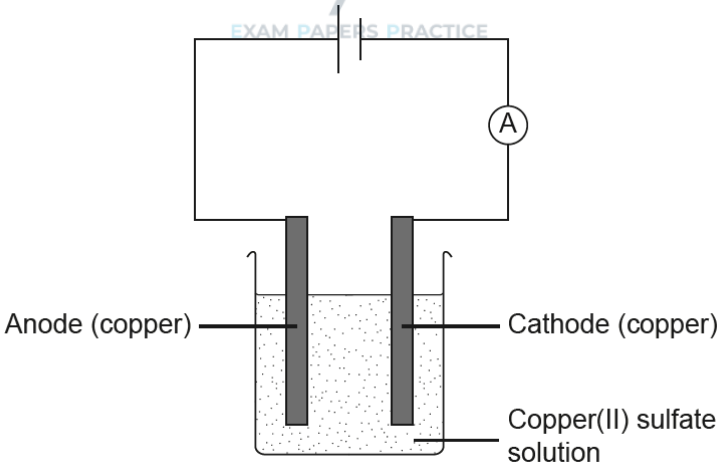
When the reaction is at equilibrium at 600 K, the concentrations of A, B, and C are 2, 1, and 2 mol dm^{-3} respectively. What is the value of the equilibrium constant at 600 K?

A. 0.25
B. 1
C. 2
D. 4

[1]

21M.1A.HL.TZ2.31

What happens to the mass of each copper electrode when aqueous copper(II) sulfate solution is electrolysed?



	Anode (positive electrode)	Cathode (negative electrode)
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

[1]

SPM.1A.HL.TZ0.33

The indicator, HInd, is used in an acid–base titration. [1]

$$\underset{\text{colour A}}{HInd\,(aq)} \rightleftharpoons \underset{\text{colour B}}{H^+(aq) + Ind^-(aq)}$$

Which statements are correct?

I. In a strongly alkaline solution, colour B is observed.
II. Colour A is observed when [HInd] < [Ind^-].
III. [Ind^-] approximately equals [HInd] at the end point.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

22N.1A.HL.TZ0.10

Which elements are capable of forming expanded octets? [1]

I. Nitrogen
II. Phosphorus
III. Arsenic

A. I and II only

B. I and III only
C. II and III only
D. I, II and III

21M.1A.HL.TZ2.36

Which compound rotates the plane of plane-polarized light? [1]
A. $CH_3C(CH_3)ClCH_3$
B. $CH_3CH_2CHClCH_3$
C. $CH_3C(Cl)_2CH_3$
D. $CH_3CClBrCH_3$

22M.1A.HL.TZ2.11

What is the formal charge of the oxygen atom in H_3O^+? [1]
A. −2
B. −1
C. 0
D. +1

19M.1A.HL.TZ1.21

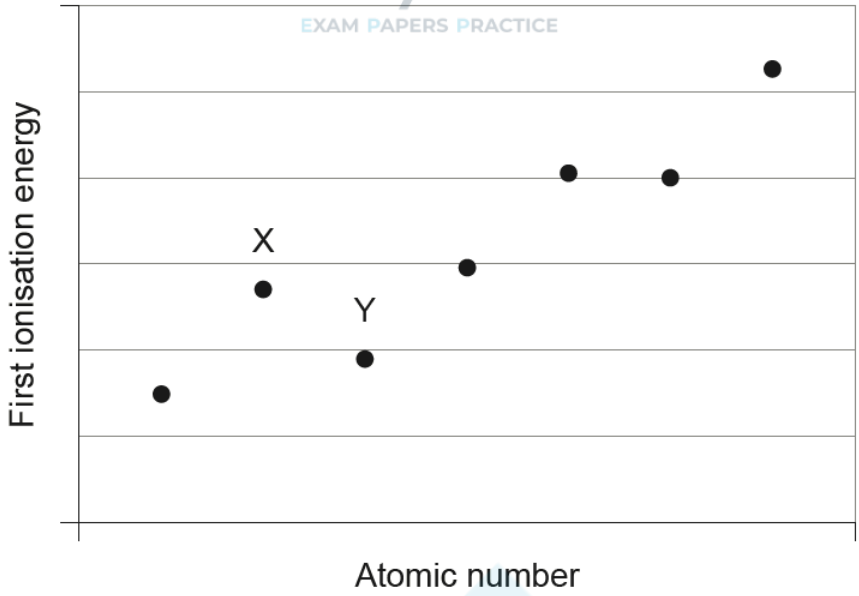
Which is correct for the reaction mechanism shown? [1]

$2A \rightarrow B + 2C$ slow
$B + C \rightarrow D + E$ fast
$C + D \rightarrow E + F$ fast

	Equation of overall reaction	Rate equation
A.	$2A \rightarrow E + F$	rate = $k[A]^2$
B.	$2A \rightarrow 2E + F$	rate = $k[C][D]$
C.	$2A + B + 2C + D \rightarrow 2E + F$	rate = $k[A]^2[B][C]^2[D]$
D.	$2A \rightarrow 2E + F$	rate = $k[A]^2$

21M.1A.HL.TZ1.6

The diagram shows the first ionisation energies of consecutive elements in the same period of the periodic table.



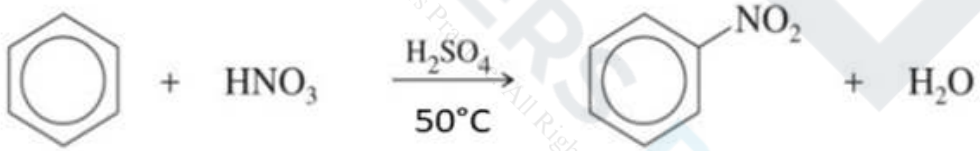
Which factor explains why element X has a higher first ionisation energy than element Y?

A. Element Y loses an electron from a different sub-level.
B. Element Y has a smaller atomic radius.
C. Element X has a full octet.
D. Element Y has a greater nuclear charge.

[1]

EXM.1A.HL.TZ0.6

Which of the following describes the role of benzene in the reaction? [1]



A. an electrophile
B. a nucleophile
C. a reducing agent
D. an acid

SPM.1A.HL.TZ0.17

What do all greenhouse gases have in common? [1]

A. They are emitted by the burning of fossil fuels.
B. They absorb ultraviolet radiation.
C. They are symmetrical molecules with no polar bonds.
D. They absorb infrared radiation.

22N.1A.HL.TZ0.20

Data is given for the reaction $2X_2(g) + Y_2(g) \rightarrow 2X_2Y(g)$.

$[X_2(g)]$ (mol dm^{-3})	$[Y_2(g)]$ (mol dm^{-3})	Rate (mol dm^{-3} min^{-1})
0.1	0.2	0.1
0.2	0.2	0.4
0.2	0.1	0.4

What rate equation can be inferred from the data?

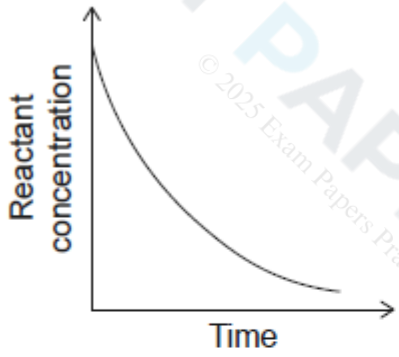
A. Rate = $k[X_2][Y_2]$
B. Rate = $k[X_2]^2[Y_2]$
C. Rate = $k[X_2]^2[Y_2]^0$
D. Rate = $k[X_2]^2[Y_2]^2$

[1]

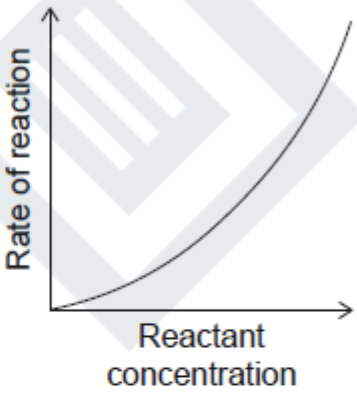
21N.1A.HL.TZ0.20

Which graph shows a first order reaction? [1]

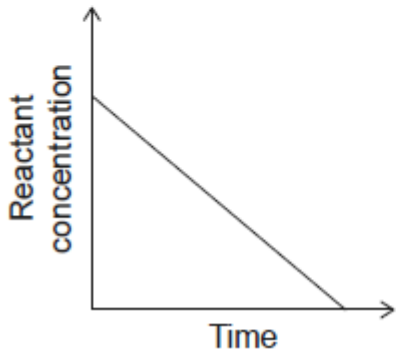
A.



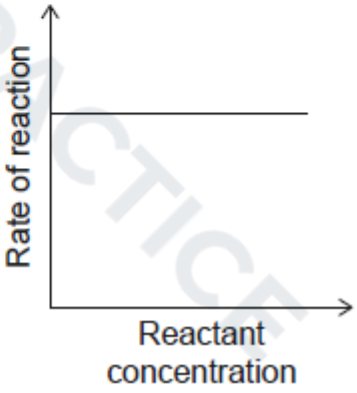
B.



C.



D.



22M.1A.HL.TZ2.12

What is the molecular geometry of SF_4? [1]
A. Tetrahedral
B. Trigonal bipyramidal
C. See-saw
D. Square planar

19N.1A.HL.TZ0.28

What is the order, in increasing pH, of the following solutions of equal concentration?

	p*Ka*		*Ka*
$CH_3CH_2CH_2COOH$	4.8	$CHCl_2COOH$	5.0×10^{-2}
CH_3CH_2COOH	4.9	H_3BO_3	5.8×10^{-10}

A. $H_3BO_3 < CH_3CH_2CH_2COOH < CH_3CH_2COOH < CHCl_2COOH$
B. $H_3BO_3 < CH_3CH_2CH_2COOH < CHCl_2COOH < CH_3CH_2COOH$
C. $CH_3CH_2CH_2COOH < CH_3CH_2COOH < CHCl_2COOH < H_3BO_3$
D. $CHCl_2COOH < CH_3CH_2CH_2COOH < CH_3CH_2COOH < H_3BO_3$

[1]

19M.1A.HL.TZ1.26

Which is a Lewis acid but not a Brønsted–Lowry acid? [1]
A. $AlCl_3$
B. CH_3CO_2H
C. HF
D. CCl_4

22N.1A.HL.TZ0.4

Successive ionization energies of an element, **X** , are shown.

	1st	2nd	3rd	4th
Ionization energy ($kJ\ mol^{-1}$)	740	1450	7730	10540

What energy, in $kJ\ mol^{-1}$, is required for element **X** to reach its most stable oxidation state in ionic compounds?

A. 740
B. 1450
C. 2190
D. 7730

[1]

SPM.1A.HL.TZ0.25

The complete combustion of 20.0 cm^3 of a gaseous hydrocarbon, C_xH_y, produces 80.0 cm^3 of gaseous products. This volume reduces to 40.0 cm^3 when the water vapour present condenses. All volumes are measured at the same temperature and pressure.

What is the molecular formula of the hydrocarbon?

A. CH_4

B. C_2H_2
C. C_2H_4
D. C_3H_6

[1]

SPM.1A.HL.TZ0.15

The block structure of the periodic table groups elements according to which characteristic?

A. atomic number
B. atomic mass
C. electron configuration
D. reactivity

[1]

19M.1A.HL.TZ2.21

What is the order with respect to each reactant?

$$2NO\ (g) + Cl_2\ (g) \rightarrow 2NOCl\ (g)$$

Initial [NO] / mol dm^{-3}	Initial [Cl_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
0.10	0.10	2.5×10^{-6}
0.10	0.20	5.0×10^{-6}
0.20	0.10	10.0×10^{-6}

	Order with respect to NO	Order with respect to Cl_2
A.	0	1
B.	1	1
C.	2	1
D.	2	2

[1]

EXM.1A.HL.TZ0.9

Which of the following statements is correct when a 1.0 M NH_4^+/NH_3 buffer (pH = 9.2) is diluted to 0.5 M with water?

I. The ability of the buffer to resist changes in pH when acids are added will decrease.
II. The ability of the buffer to resist changes in pH when bases are added will decrease.
III. The pH of the buffer will be equal to 7.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

[1]

SPM.1A.HL.TZ0.24

What is correct as a system approaches equilibrium? [1]

A. Q remains constant.
B. K_c increases.
C. $\Delta G^{\ominus}$ becomes more negative.
D. ΔG approaches zero.

SPM.1A.HL.TZ0.2

Ice containing only the isotope ^2H sinks and does not melt when dropped into ordinary distilled water maintained at 3 °C.

Which statement is correct?

A. The isotope ^2H has a high natural abundance.
B. ^2H_2O (s) has a higher melting point than normal ice.
C. ^2H_2O (s) has a lower density than normal ice-cold water.
D. ^2H_2O has different chemical properties from normal water.

[1]

19M.1A.HL.TZ1.18

K_c for $2N_2O(g) \rightleftharpoons 2N_2(g) + O_2(g)$ is 7.3×10^{34}. [1]
What is K_c for the following reaction, at the same temperature?

$$N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons N_2O(g)$$

A. 7.3×10^{34}
B. $\frac{1}{\sqrt{7.3 \times 10^{34}}}$
C. $\frac{2}{7.3 \times 10^{34}}$
D. $\frac{1}{2 \times 7.3 \times 10^{34}}$

22M.1A.HL.TZ2.17

Which term in the expression $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ is an indirect measure of the entropy change of the surroundings when divided by T?

A. $\Delta G^{\ominus}$
B. $\Delta H^{\ominus}$
C. $\Delta S^{\ominus}$
D. $-T\Delta S^{\ominus}$

[1]

22N.1A.HL.TZ0.30

The standard electrode potentials for three half-cells involving chromium are shown. [1]

$$Cr^{3+}(aq) + e^{-} \rightleftharpoons Cr^{2+}(aq) \quad E^{\ominus} = -0.407\,V$$
$$Cr^{3+}(aq) + 3e^{-} \rightleftharpoons Cr(s) \quad E^{\ominus} = -0.744\,V$$
$$Cr^{2+}(aq) + 2e^{-} \rightleftharpoons Cr(s) \quad E^{\ominus} = -0.914\,V$$

Which statement is correct?

A. $Cr^{3+}(aq)$ can oxidize $Cr^{2+}(aq)$ but not Cr (s).
B. $Cr^{3+}(aq)$ can oxidize Cr (s) but not $Cr^{2+}(aq)$.
C. $Cr^{3+}(aq)$ can oxidize both $Cr^{2+}(aq)$ and Cr (s).
D. $Cr^{3+}(aq)$ can oxidize Cr (s) and reduce $Cr^{2+}(aq)$.

SPM.1A.HL.TZ0.34

The overall reaction occurring at the electrodes of a rechargeable metal hydride battery can be summarized as:

$$MH + NiO(OH) \rightleftharpoons M + Ni(OH)_2$$

Which statement is correct?

A. The oxidation state of Ni does not change.
B. M is oxidized by loss of hydrogen.
C. The oxidation state of one H atom changes from -1 to +1.
D. The oxidation state of one O atom changes from -1 to -2.

[1]

19M.1A.HL.TZ1.17

Which equation represents the standard enthalpy of atomization of bromine, Br_2? [1]

A. $\frac{1}{2} Br_2(l) \rightarrow Br(g)$
B. $Br_2(l) \rightarrow 2Br(g)$
C. $Br_2(l) \rightarrow 2Br(l)$
D. $\frac{1}{2} Br_2(l) \rightarrow Br(l)$

SPM.1A.HL.TZ0.23

Which are endothermic processes in a Born–Haber cycle for the formation of an ionic compound?

I. Enthalpy of atomization
II. First electron affinity
III. First ionization energy

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

[1]

21M.1A.HL.TZ1.16

The table shows the variation of standard Gibbs energy with temperature for a reversible reaction.

$$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$$
$$\Delta G^{\ominus} = -RT \ln K$$

Temperature / K	$\Delta G^{\ominus}$ / kJ mol^{-1}
298	5.4
350	−3.9
400	−12.9

What can be concluded about the reaction?
A. Equilibrium shifts left as temperature increases.
B. The forward reaction is more spontaneous below 300 K.
C. Entropy is higher in the products than in the reactants.
D. K_c decreases as temperature increases.

[1]

SPM.1A.HL.TZ0.3

The table lists successive ionization energies of an element **Z** .

Ionization number	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Ionization energy / kJ mol−1	577.54	1816.68	2744.78	11 577.5	14 841.9	18 379

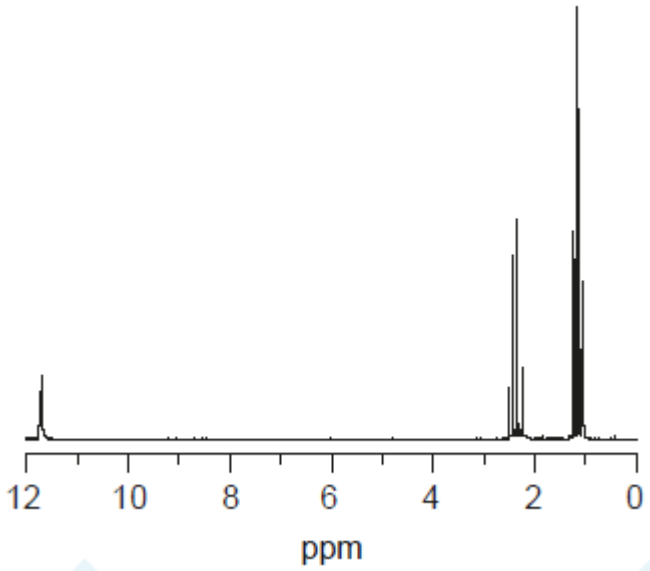
Which is the formula of the stable oxide of the element **Z** ?

A. Z_2O
B. ZO
C. Z_2O_3
D. ZO_2

[1]

22N.1A.HL.TZ0.40

Which organic compound has the ^{1}H NMR shown? [1]



A. Methanal
B. Ethanoic acid
C. Methyl ethanoate
D. Propanoic acid

19N.1A.HL.TZ0.11

Which describes a resonance structure? [1]
A. Double bond can be drawn in alternative positions.
B. Bonds vibrate by absorbing IR radiation.
C. A double and a single bond in the molecule
D. A Lewis structure

21M.1A.HL.TZ2.37

Which can be reduced to a secondary alcohol? [1]
A. C_2H_5COOH
B. $CH_3CH_2OCH_3$
C. $(CH_3)_2CHCHO$
D. $CH_3COC_2H_5$

19M.1A.HL.TZ1.36

Which statement is **not** correct regarding benzene? [1]
A. It is planar.
B. The ring contains delocalized electrons.
C. It always reacts in the same way as alkenes.
D. The carbon–carbon bond has a bond order of 1.5.

19M.1A.HL.TZ2.22

Consider the following equilibrium reaction. [1]

$2N_2O\,(g) + O_2\,(g) \rightleftharpoons 4NO\,(g)\ \Delta H = +16\ kJ$

Which change will move the equilibrium to the right?

A. Decrease in pressure
B. Decrease in temperature
C. Increase in [NO]
D. Decrease in $[O_2]$

22N.1A.HL.TZ0.29

What is the coefficient for H^+ when the equation below is balanced? [1]

$\_\_Pb\,(s) + \_\_NO_3^-\,(aq) + \_\_H^+\,(aq) \rightarrow \_\_Pb^{2+}\,(aq) + \_\_NO\,(g) + \_\_H_2O\,(l)$

A. 2
B. 4
C. 6
D. 8

21N.1A.HL.TZ0.12

Which molecules contain two pi (π) bonds? [1]

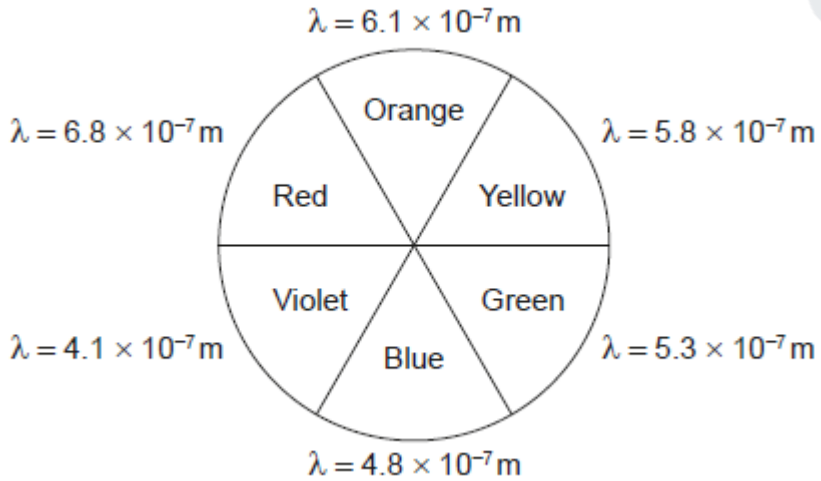
I. HCN
II. H_2CO_3
III. $H_2C_2O_4$

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

22M.1A.HL.TZ2.8

$[Cr(OH_2)_6]^{3+}$ is violet and $[Cr(NH_3)_6]^{3+}$ is yellow. What is correct? [1]

The Colour Wheel

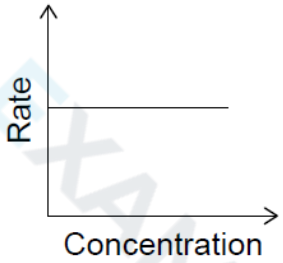


	Wavelength of light absorbed by $[Cr(OH_2)_6]^{3+}$	d-level splitting caused by H_2O compared to NH_3 ligands
A.	$\lambda = 5.8 \times 10^{-7}$ m	$H_2O > NH_3$
B.	$\lambda = 5.8 \times 10^{-7}$ m	$H_2O < NH_3$
C.	$\lambda = 4.1 \times 10^{-7}$ m	$H_2O > NH_3$
D.	$\lambda = 4.1 \times 10^{-7}$ m	$H_2O < NH_3$

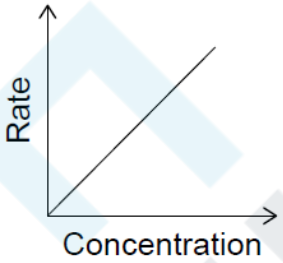
19M.1A.HL.TZ1.20

Which graph is obtained from a first order reaction? [1]

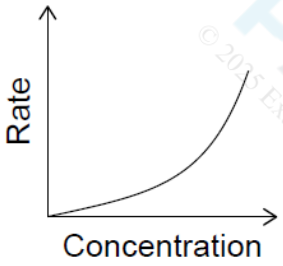
A.



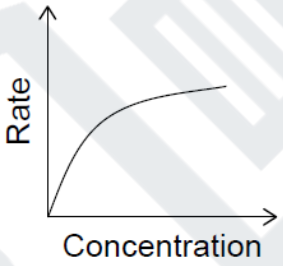
B.



C.



D.



22M.1A.HL.TZ1.30

What are the products when dilute aqueous copper (II) nitrate is electrolysed using platinum electrodes?

$E^{\ominus}(Cu \mid Cu^{2+}) = -0.34$ V.

	Anode (positive electrode)	Cathode (negative electrode)
A.	$O_2(g)$	$Cu(s)$
B.	$O_2(g)$	$H_2(g)$
C.	$Cu(s)$	$O_2(g)$
D.	$H_2(g)$	$Cu(s)$

[1]

19N.1A.HL.TZ0.12

Which atom is sp^2 hybridized? [1]

A. C in H_2CO
B. C in CO_2
C. N in CH_3NH_2
D. O in H_2O

SPM.1A.HL.TZ0.1

What is thin-layer chromatography best used for separating? [1]

A. molecules of varying polarity
B. molecules of similar polarity
C. metals in an alloy
D. water of crystallization from hydrated salts