IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

Chemistry
Higher level and standard level

Specimen paper 1s, 2s and 3s

For first examinations in 2009

CONTENTS

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

CHEMISTRY
HIGHER LEVEL
PAPER 1

SPECIMEN PAPER

1 hour

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.

The Periodic Table

1	2											3	4	5	6	7	0
1 **H** 1.01				Atomic Number **Element** Atomic Mass													2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)															

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1. How many hydrogen atoms are in one mole of ethanol, C_2H_5OH?

A. 1.00×10^{23}

B. 3.61×10^{24}

C. 5.00

D. 6.00

2. What is the coefficient of $H_2SO_4(aq)$ when the following equation is balanced, using the smallest possible integers?

$$\_\_Mg_3N_2(s) + \_\_H_2SO_4(aq) \rightarrow \_\_MgSO_4(aq) + \_\_(NH_4)_2SO_4(aq)$$

A. 1

B. 3

C. 4

D. 7

3. What volume, in cm^3, of 0.200 mol dm^{-3} HCl (aq) is required to neutralize 25.0 cm^3 of 0.200 mol dm^{-3} $Ba(OH)_2(aq)$?

A. 12.5

B. 25.0

C. 50.0

D. 75.0

4. Which species has 54 electrons and 52 protons?

A. $^{128}_{52}Te^{2-}$

B. $^{132}_{54}Xe^{2+}$

C. $^{132}_{54}Xe^{2-}$

D. $^{128}_{52}Te^{2+}$

5. What is the correct sequence for the processes occurring in a mass spectrometer?

A. vaporization, ionization, acceleration, deflection

B. vaporization, acceleration, ionization, deflection

C. ionization, vaporization, acceleration, deflection

D. ionization, vaporization, deflection, acceleration

6. What is the electron configuration for the copper(I) ion, ($Z = 29$)?

A. $[Ar]4s^2 3d^9$

B. $[Ar]4s^1 3d^{10}$

C. $[Ar]4s^1 3d^9$

D. $[Ar]3d^{10}$

7. Which series is arranged in order of **increasing** radius?

A. $Ca^{2+} < Cl^- < K^+$

B. $K^+ < Ca^{2+} < Cl^-$

C. $Ca^{2+} < K^+ < Cl^-$

D. $Cl^- < K^+ < Ca^{2+}$

8. Which salts form coloured solutions when dissolved in water?

I. $FeCl_3$
II. $NiCl_2$
III. $ZnCl_2$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. How many electrons are used in the carbon-carbon bond in C_2H_2?

A. 4

B. 6

C. 10

D. 12

10. What type of solid materials are typically hard, have high melting points and poor electrical conductivities?

I. Ionic
II. Metallic
III. Covalent-network

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. How many sigma (σ) and pi (π) bonds are present in the structure of HCN?

	σ	**π**
A.	1	3
B.	2	3
C.	2	2
D.	3	1

12. How many lone pairs and bonding pairs of electrons surround xenon in the XeF_4 molecule?

	Lone pairs	**Bonding pairs**
A.	4	8
B.	0	8
C.	0	4
D.	2	4

13. Using the equations below:

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -394 \text{ kJ mol}^{-1}$$

$$Mn(s) + O_2(g) \rightarrow MnO_2(s) \qquad \Delta H^{\ominus} = -520 \text{ kJ mol}^{-1}$$

What is ΔH, in kJ, for the following reaction?

$$MnO_2(s) + C(s) \rightarrow Mn(s) + CO_2(g)$$

A. 914

B. 126

C. −126

D. −914

14. Which reaction has the most negative $\Delta H^{\ominus}$ value?

A. $LiF(s) \rightarrow Li^+(g) + F^-(g)$

B. $Li^+(g) + F^-(g) \rightarrow LiF(s)$

C. $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

D. $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

15. Which equation represents the electron affinity of calcium?

A. $Ca(g) \rightarrow Ca^+(g) + e^-$

B. $Ca(g) \rightarrow Ca^-(g) + e^-$

C. $Ca(g) + e^- \rightarrow Ca^-(g)$

D. $Ca^+(g) + e^- \rightarrow Ca(g)$

16. Which reaction causes a decrease in the entropy of the system?

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

B. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

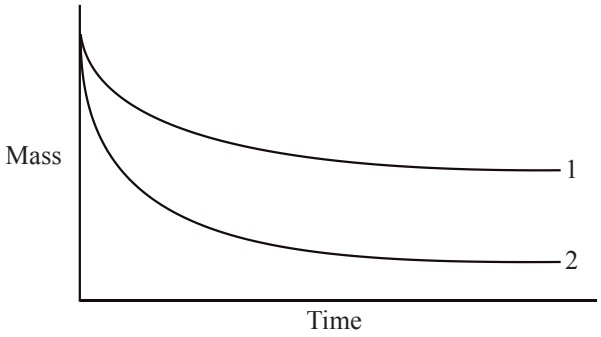
C. $2C(s) + O_2(g) \rightarrow 2CO(g)$

D. $2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$

17. What are the signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for a reaction that is non-spontaneous at low temperature but spontaneous at high temperature?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	–	–
B.	+	–
C.	–	+
D.	+	+

18. Excess magnesium, was added to a beaker of aqueous hydrochloric acid. A graph of the mass of the beaker and contents was plotted against time (line 1).



What change in the experiment could give line 2?

A. The same mass of magnesium in smaller pieces

B. The same volume of a more concentrated solution of hydrochloric acid

C. A lower temperature

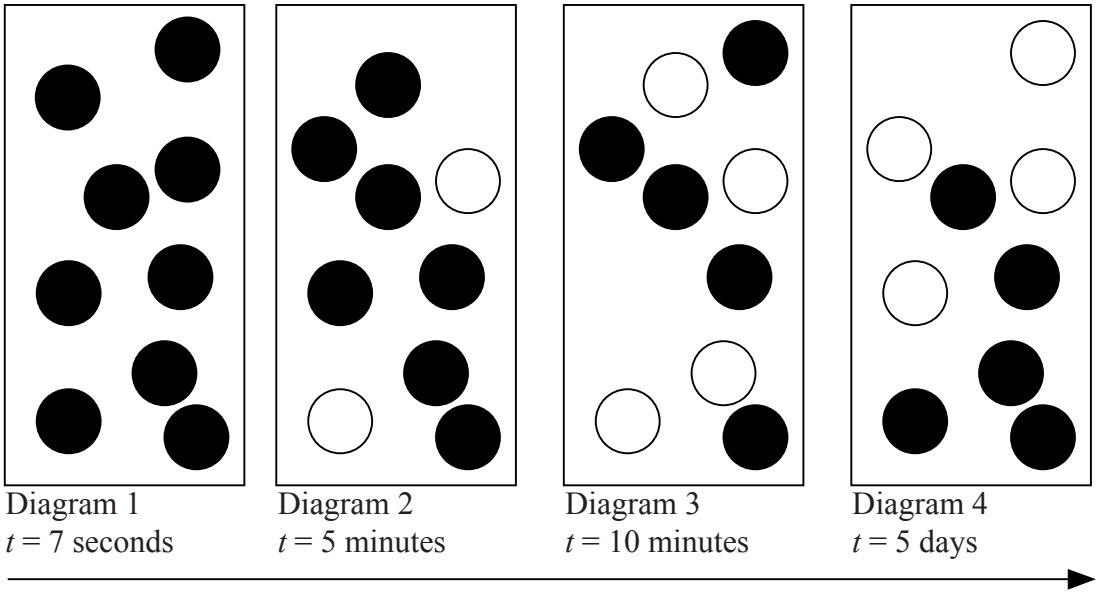
D. A more accurate instrument to measure the time

19. What is the order of reaction with respect to $NO_2(g)$ and $F_2(g)$ given the following rate data at a certain temperature?

$[NO_2(g)]$ / mol dm^{-3}	$[F_2(g)]$ / mol dm^{-3}	Rate / mol dm^{-3} min^{-1}
0.1	0.2	0.1
0.2	0.2	0.4
0.1	0.4	0.2

	Order with respect to $NO_2(g)$	Order with respect to $F_2(g)$
A.	first	first
B.	first	second
C.	second	first
D.	second	second

20. The sequence of diagrams shown represents the system as time passes for a gas phase reaction in which reactant **X** is converted to product **Y**.



Which statement is correct?

A. At $t = 5$ days the rate of the forward reaction is greater than the rate of the backward reaction.

B. At $t = 7$ seconds the reaction has reached completion.

C. At $t = 10$ minutes the system has reached a state of equilibrium.

D. At $t = 5$ days the rate of the forward reaction is less than the rate of the backward reaction.

21. For the reaction below:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

at a certain temperature, the equilibrium concentrations, in mol dm^{-3}, are

$$[H_2(g)] = 0.30,\ [I_2(g)] = 0.30,\ [HI(g)] = 3.0$$

What is the value of K_c?

A. 1.0×10^{-2}

B. 10

C. 33

D. 1.0×10^{2}

22. A liquid and its vapour are at equilibrium inside a sealed container. Which change will alter the equilibrium vapour pressure of the liquid in the container?

A. Adding more liquid

B. Adding more vapour

C. Decreasing the volume of the container

D. Decreasing the temperature

23. Which species can act as a Lewis acid?

A. BF_3

B. OH^-

C. H_2O

D. NH_3

24. Which methods will distinguish between equimolar solutions of a strong base and a strong acid?

I. Add magnesium to each solution and look for the formation of gas bubbles.

II. Add aqueous sodium hydroxide to each solution and measure the temperature change.

III. Use each solution in a circuit with a battery and lamp and see how bright the lamp glows.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

25. Which values are correct for a 0.010 mol dm^{-3} solution of NaOH (aq) at 298 K?
($K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K)

A. $[H^+] = 1.0 \times 10^{-12}$ mol dm^{-3} and pH = 12.00

B. $[OH^-] = 1.0 \times 10^{-12}$ mol dm^{-3} and pH = 12.00

C. $[H^+] = 1.0 \times 10^{-12}$ mol dm^{-3} and pOH = 12.00

D. $[OH^-] = 1.0 \times 10^{-12}$ mol dm^{-3} and pOH = 12.00

26. At 25°C, K_a for an acid is 1.0×10^{-2}. What is the value of K_b for its conjugate base?

A. 1.0×10^{2}

B. 1.0×10^{-2}

C. 1.0×10^{12}

D. 1.0×10^{-12}

27. Which statement about indicators is **always** correct?

A. The mid-point of the pH range of an indicator is 7.

B. The pH range is greater for indicators with higher pK_a values.

C. The colour red indicates an acidic solution.

D. The pK_a value of the indicator is within its pH range.

28. Consider the following reaction:

$$H_2SO_3(aq) + Sn^{4+}(aq) + H_2O(l) \rightarrow Sn^{2+}(aq) + HSO_4^-(aq) + 3H^+(aq)$$

Which statement is correct?

A. H_2SO_3 is the reducing agent because it undergoes reduction.

B. H_2SO_3 is the reducing agent because it undergoes oxidation.

C. Sn^{4+} is the oxidizing agent because it undergoes oxidation.

D. Sn^{4+} is the reducing agent because it undergoes oxidation.

29. Which processes occur during the electrolysis of molten sodium chloride?

I. Sodium and chloride ions move through the electrolyte.
II. Electrons move through the external circuit.
III. Oxidation takes place at the anode.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Which equation represents the reduction process occurring in the standard hydrogen electrode?

A. $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

B. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

C. $2H^+(aq) + 2e^- \rightarrow H_2(g)$

D. $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

31. Which statement is correct about the value of $E^{\ominus}$?

A. The more positive the value of $E^{\ominus}$, the greater the driving force for reduction.

B. The more negative the value of $E^{\ominus}$, the greater the driving force for reduction.

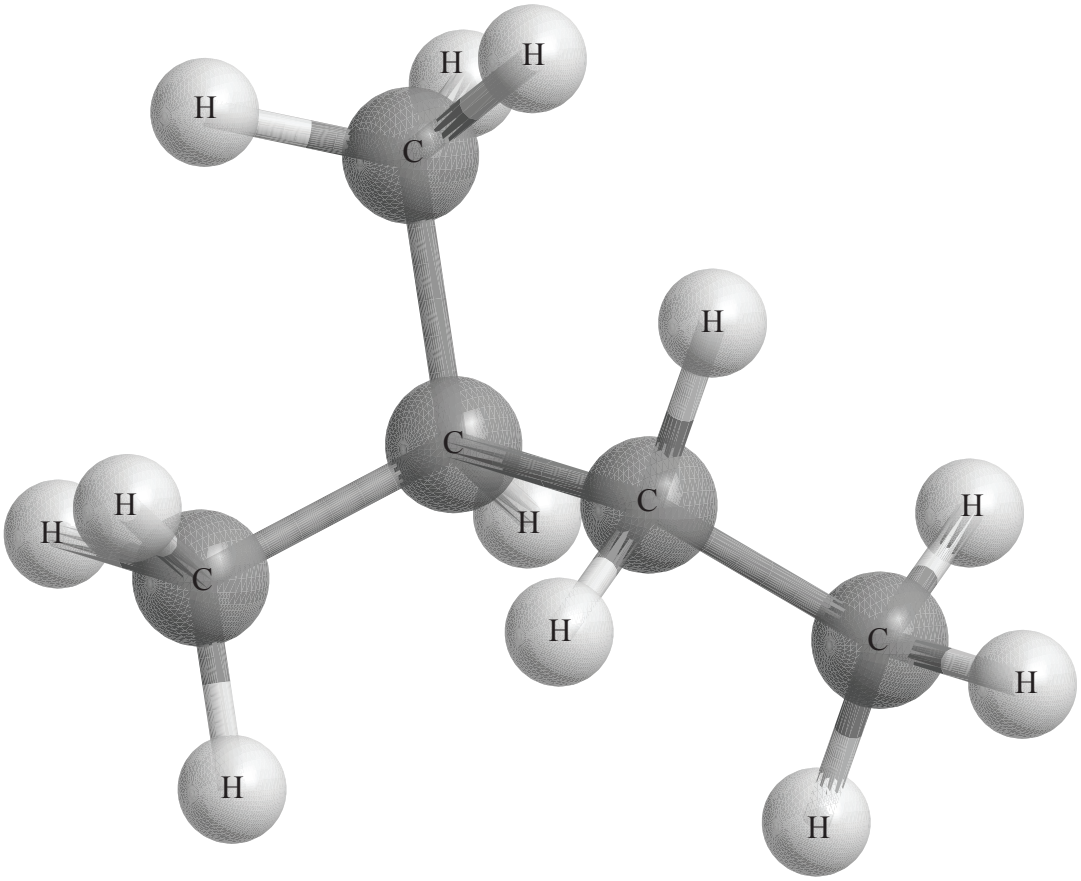
C. The more positive the value of $E^{\ominus}$, the greater the rate of reaction.

D. The more negative the value of $E^{\ominus}$, the greater the rate of reaction.

32. Which combination is correct for the complex ion in $[Co(NH_3)_4(H_2O)Cl]Br$?

	Oxidation state of cobalt	**Shape of the complex ion**	**Overall charge of the complex ion**
A.	+2	Octahedral	+2
B.	+3	Octahedral	–1
C	+2	Octahedral	+1
D.	+2	Tetrahedral	+1

33. The following is a three-dimensional representation of an organic molecule.



Which statement is correct?

A. The correct IUPAC name of the molecule is 2-methylpentane.

B. All the bond angles will be approximately 90°.

C. One isomer of this molecule is pentane.

D. The boiling point of this compound would be higher than that of pentane.

34. What compound forms when hydrogen bromide is added to but-2-ene?

A. 2-bromobutane

B. 2,3-dibromobutane

C. 1-bromobutane

D. 1,2-dibromobutane

35. Which products can be potentially obtained from crude oil and are economically important?

I. Plastics
II. Margarine
III. Motor fuel

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

36. What is the product of the following reaction?

$$CH_3CH_2CH_2CN + H_2 \xrightarrow{Ni}$$

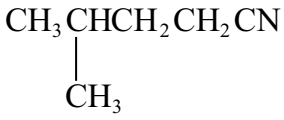
A. $CH_3CH_2CH_2NH_2$

B. $CH_3CH_2CH_2CH_3$

C. $CH_3CH_2CH_2CH_2CH_3$

D. $CH_3CH_2CH_2CH_2NH_2$

37. What is the correct IUPAC name for the following compound?



A. 4-methylbutanenitrile

B. 4-methylpentanenitrile

C. 2-methylbutanenitrile

D. 2-methylpentanenitrile

38. What is the organic product of the reaction between ethanol and ethanoic acid in the presence of sulfuric acid?

A. CH_3CHO

B. CH_3COOCH_3

C. $CH_3CH_2COOCH_3$

D. $CH_3COOCH_2CH_3$

39. Which compound can exist as optical isomers?

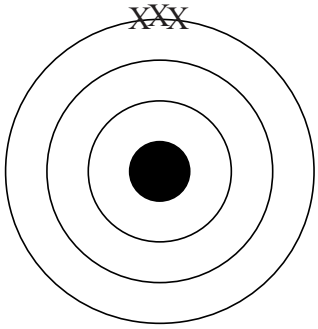
A. H_2NCH_2COOH

B. H_3CCONH_2

C. $H_3CCHBrI$

D. $HCOOCH_3$

40. The following diagram shows a set of experimental data points, X, determined when one experimental measurement was repeated three times. The centre of the diagram represents the ideal value calculated from theory. What statement is correct about these measurements?



A. The measurements involve low accuracy and low precision.

B. The measurements involve low accuracy and high precision.

C. The measurements involve high accuracy and low precision.

D. The measurements involve high accuracy and high precision.

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PROGRAMA DEL DIPLOMA DEL BI

SPEC/4/CHEMI/HPM/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Higher Level

Paper 1

2 pages

1.	B	16.	B	31.	A	46.	–
2.	C	17.	D	32.	C	47.	–
3.	C	18.	B	33.	C	48.	–
4.	A	19.	C	34.	A	49.	–
5.	A	20.	C	35.	B	50.	–
6.	D	21.	D	36.	D	51.	–
7.	C	22.	D	37.	B	52.	–
8.	A	23.	A	38.	D	53.	–
9.	A	24.	A	39.	C	54.	–
10.	B	25.	A	40.	B	55.	–
11.	C	26.	D	41.	–	56.	–
12.	D	27.	D	42.	–	57.	–
13.	B	28.	B	43.	–	58.	–
14.	B	29.	D	44.	–	59.	–
15.	C	30.	C	45.	–	60.	–

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

CHEMISTRY
HIGHER LEVEL
PAPER 2

SPECIMEN PAPER

2 hours 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

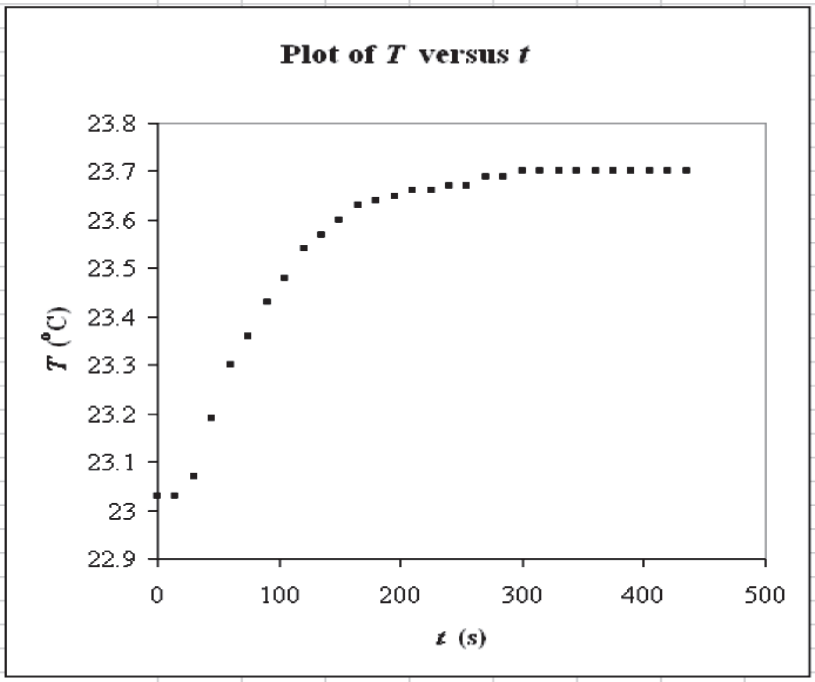
SECTION A

*Answer **all** the questions in the spaces provided.*

1. The data below is from an experiment used to measure the enthalpy change for the combustion of 1 mole of sucrose (common table sugar), $C_{12}H_{22}O_{11}(s)$. The time-temperature data was taken from a data-logging software programme.

	A	B
1	**Time (s)**	**Temperature (°C)**
2	0	23.03
3	15	23.03
4	30	23.07
5	45	23.19
6	60	23.3
7	75	23.36
8	90	23.43
9	105	23.48
10	120	23.54
11	135	23.57
12	150	23.6
13	165	23.63
14	180	23.64
15	195	23.65
16	210	23.66
17	225	23.66
18	240	23.67
19	255	23.67
20	270	23.69
21	285	23.69
22	300	23.7
23	315	23.7
24	330	23.7
25	345	23.7
26	360	23.7
27	375	23.7
28	390	23.7
29	405	23.7
30	420	23.7
31	435	23.7
32		
33		
34		
35		

Sheet1 / Sheet2 / Sheet3 /



Mass of sample of sucrose, $m = 0.4385$ g

Heat capacity of the system, $C_{system} = 10.114$ kJ K^{-1}

(a) Calculate ΔT, for the water, surrounding the chamber in the calorimeter. *[1]*

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(b) Determine the amount, in moles, of sucrose. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(c) (i) Calculate the enthalpy change for the combustion of 1 mole of sucrose. *[1]*

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(ii) Using Table 12 of the Data Booklet, calculate the percentage experimental error based on the data used in this experiment. *[1]*

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(d) A hypothesis is suggested that TNT, 2-methyl-1,3,5-trinitrobenzene, is a powerful explosive because it has:

- a large enthalpy of combustion
- a high reaction rate
- a large volume of gas generated upon combustion

Use your answer in part (c)(i) and the following data to evaluate this hypothesis.

	Equation for combustion	**Relative rate of combustion**	**Enthalpy of combustion / kJ mol^{-1}**
Sucrose	$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(g)$	Low	
TNT	$2C_7H_5N_3O_6(s) \rightarrow 7CO(g) + 7C(s) + 5H_2O(g) + 3N_2(g)$	High	3406

[3]

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2. Nitrogen(II) oxide reacts with hydrogen according to the following equation:

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The table shows how the rate of reaction varies as the concentrations of the reactants are changed.

Experiment	**Initial [NO] / mol dm^{-3}**	**Initial [H_2] / mol dm^{-3}**	**Initial rate / mol (N_2) dm^{-3} s^{-1}**
1	0.100	0.100	2.53×10^{-6}
2	0.100	0.200	5.05×10^{-6}
3	0.200	0.100	1.01×10^{-5}
4	0.300	0.100	2.28×10^{-5}

(a) Determine the order of reaction with respect to H_2 and with respect to NO. *[2]*

H_2 . . . . . .

NO. . . . . .

(b) Write the rate expression for the reaction. *[1]*

. . . . . .

(c) Calculate the value for the rate constant, and state its units using the data from experiment 1. *[2]*

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(This question continues on the following page)

(Question 2 continued)

(d) A suggested mechanism for this reaction is as follows.

$H_2 + NO \rightleftharpoons X$ fast step
$X + NO \rightarrow Y + H_2O$ slow step
$Y + H_2 \rightarrow N_2 + H_2O$ fast step

State and explain whether this mechanism agrees with the experimental rate expression in (b). *[4]*

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(e) Explain why a single step mechanism is unlikely for a reaction of this kind. *[2]*

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(f) Deduce and explain how the initial rate of formation of H_2O compares with that of N_2. *[2]*

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3. A table of standard electrode potentials can be found in Table 14 of the Data Booklet.

(a) Describe the materials and conditions used in the standard hydrogen electrode. *[5]*

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(b) Define the term *oxidizing agent* in terms of electron transfer and identify the strongest oxidizing agent in Table 14 of the Data Booklet. *[2]*

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(c) A cell was set up using tin in tin(II) sulfate solution and copper in copper(II) sulfate solution, with both solutions under standard conditions.

(i) Calculate the cell potential. *[1]*

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(ii) Write an equation for the spontaneous cell reaction. *[2]*

. . . . . .

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4. (a) Predict and explain, using equations where appropriate, whether the following solutions are acidic, alkaline or neutral.

(i) 0.1 mol dm^{-3} $FeCl_3(aq)$ *[1]*

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(ii) 0.1 mol dm^{-3} $NaNO_3(aq)$ *[1]*

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(iii) 0.1 mol dm^{-3} $Na_2CO_3(aq)$ *[1]*

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(b) Acidic gases can be released into the atmosphere that have an environmental impact when they are deposited as acid rain. State **two** elements that form the acidic gases and describe **two** impacts they have on the natural environment. *[3]*

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5. The molecular formula, $C_3H_4Cl_2$ represents several isomeric compounds. Some isomers are cyclic and some are unsaturated.

(a) Draw the structures of two cyclic compounds that are structural isomers and state the names of both isomers. *[2]*

(b) Two of the non-cyclic compounds have geometrical isomers. Draw the structures of these compounds and their geometrical isomers. *[2]*

SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

6. (a) (i) Apply the VSEPR theory to deduce the shape of NO_2^-, ICl_5 and SF_4. For each species, draw the Lewis (electron dot) structure, name the shape, and state the value of the bond angle(s). *[9]*

(ii) Discuss the bond angle(s) in SF_4. *[1]*

(iii) Explain the hybridization involved in the C_2H_4 molecule. *[4]*

(iv) State the hybridization involved in the NO_2^- ion and comment on the nitrogen-oxygen bond distances. *[2]*

(v) Using Table 7 of the Data Booklet, predict and explain which of the bonds O-H, O-N or N-H would be most polar. *[2]*

(b) Consider the transition metal complex, $K_3[Fe(CN)_6]$.

(i) Define the term *ligand*, and identify the ligand in this complex. *[1]*

(ii) Write the full electron configuration and draw the orbital box diagram of iron in its oxidation state in this complex, and hence, determine the number of unpaired electrons in this state. *[3]*

(iii) Explain why many transition metal d-block complexes are coloured. *[3]*

7. An experiment was carried out to determine the concentration of aqueous ammonia by titrating it with a 0.150 mol dm^{-3} sulfuric acid solution. It was found that 25.0 cm^3 of the aqueous ammonia required 20.1 cm^3 of the sulfuric acid solution for neutralization.

(a) Write the equation for the reaction and calculate the concentration, in mol dm^{-3}, of the aqueous ammonia. *[4]*

(b) Several acid-base indicators are listed in Table 16 of the Data Booklet. Identify **one** indicator that could be used for this experiment. Explain your answer. *[3]*

(c) (i) Determine the pOH of 0.121 mol dm^{-3} aqueous ammonia ($pK_b = 4.75$). *[4]*

(ii) State what is meant by the term *buffer solution*, and describe the composition of an acid buffer solution in general terms. *[3]*

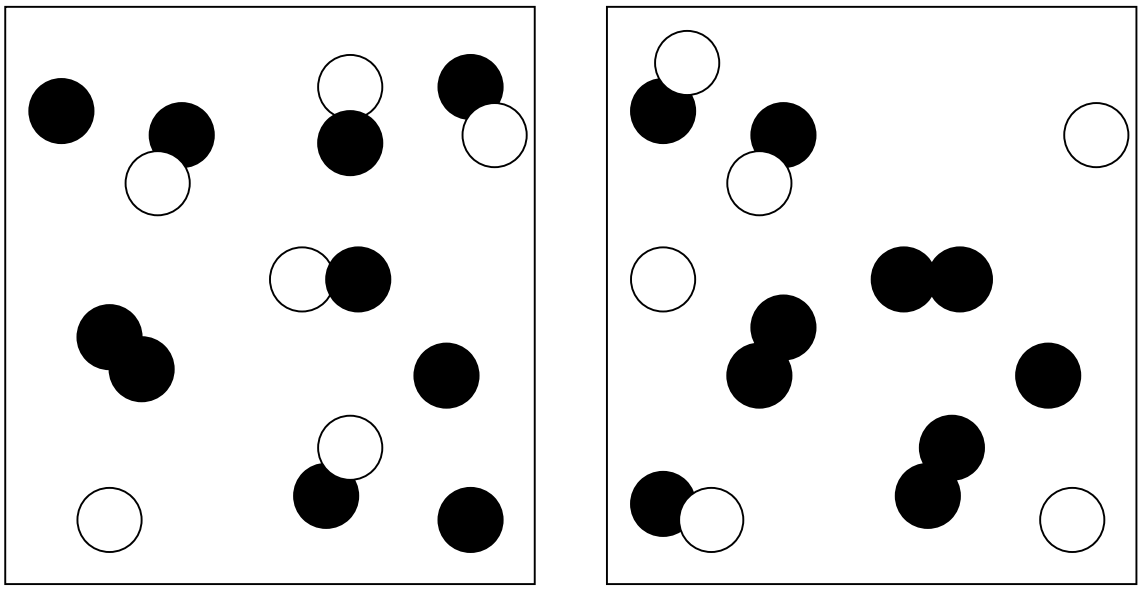
(iii) Calculate the pH of a mixture of 50.0 cm^3 of 0.100 mol dm^{-3} aqueous ammonia and 50.0 cm^3 of 0.0500 mol dm^{-3} hydrochloric acid solution. *[4]*

(d) By reference to the structure and bonding in NaCl and $SiCl_4$:

(i) State and explain the differences in electrical conductivity in the liquid state. *[3]*

(ii) Predict an approximate pH value for the solutions formed by adding each compound separately to water. Explain your answer. *[4]*

8. (a) The diagrams below represent equilibrium mixtures for the reaction $Y + X_2 \rightleftharpoons XY + X$ at 350 K and 550 K respectively. Deduce and explain whether the reaction is exothermic or endothermic. *[2]*



350 K 550 K

X =

Y =

(b) A toxic gas, A, consists of 53.8% nitrogen and 46.2% carbon by mass. At 273 K and 1.01×10^5 Pa, 1.048 g of A occupies 462 cm^3. Determine the empirical formula of A. Calculate the molar mass of the compound and determine its molecular structure. *[3]*

(This question continues on the following page)

(Question 8 continued)

(c) Consider the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Suggest why this reaction is important for humanity. *[1]*

(ii) Using the average bond enthalpy values in Table 10 of the Data Booklet, calculate the standard enthalpy change for this reaction. *[4]*

(iii) The absolute entropy values, S, at 298 K for $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are 192, 131 and 193 $JK^{-1}\,mol^{-1}$ respectively. Calculate $\Delta S^{\ominus}$ for the reaction and explain the sign of $\Delta S^{\ominus}$. *[2]*

(iv) Calculate $\Delta G^{\ominus}$ for the reaction at 298 K. State and explain whether the reaction is spontaneous. *[3]*

(v) If ammonia was produced as a liquid and not as a gas, state and explain the effect this would have on the value of $\Delta H^{\ominus}$ for the reaction. *[2]*

(d) (i) Define the terms *lattice enthalpy* and *electron affinity*. *[2]*

(ii) Use the data in the following table and from the data booklet to construct the Born-Haber cycle for sodium chloride, NaCl and determine the lattice enthalpy of NaCl(s).

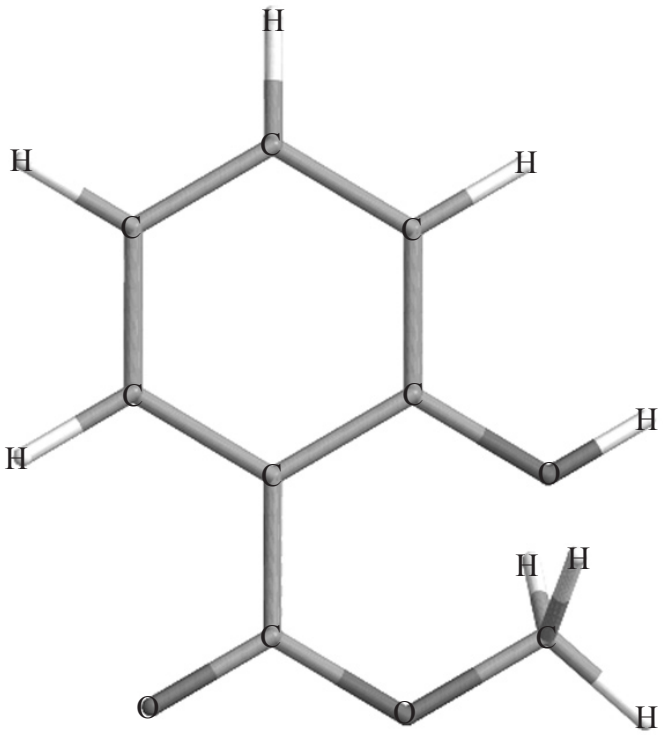
[4]

$Na(s) + \frac{1}{2}Cl_2(g) \rightarrow NaCl(g) \quad \Delta H^{\ominus} = -411\ kJ\ mol^{-1}$

$Na(s) \rightarrow Na(g) \quad \Delta H^{\ominus} = +108\ kJ\ mol^{-1}$

(iii) Describe the structure of sodium chloride. *[2]*

9. (a) The following is a computer-generated representation of the molecule, methyl 2-hydroxy benzoate, better known as oil of wintergreen.



(i) Deduce the empirical formula of methyl 2-hydroxy benzoate and draw the full structural formula, including any multiple bonds that may be present. The computer-generated representation shown does not distinguish between single and multiple bonds. *[2]*

(ii) In this representation, two of the carbon-oxygen bond lengths shown are 0.1424 nm and 0.1373 nm. Explain why these are different and predict the carbon-oxygen bond length in carbon dioxide. *[2]*

(iii) Name all the functional groups present in the molecule. *[2]*

(This question continues on the following page)

(Question 9 continued)

(b) (i) Identify the formulas of the organic products, A-E, formed in the reactions, **I** – **IV**: *[5]*

I. $CH_3(CH_2)_8OH + K_2Cr_2O_7 \xrightarrow{H^+} \mathbf{A} \xrightarrow{H^+} \mathbf{B}$

II. $(CH_3)_3CBr + NaOH \longrightarrow \mathbf{C}$

III. $(CH_3)_2CHOH + K_2Cr_2O_7 \xrightarrow{H^+} \mathbf{D}$

IV. $H_2C{=}CH_2 + Br_2 \longrightarrow \mathbf{E}$

(ii) $H_2C{=}CH_2$ can react to form a polymer. Name this **type** of polymer and draw the structural formula of a section of this polymer consisting of three repeating units. *[2]*

(c) The compound, 2-bromobutane, $CH_3CHBrCH_2CH_3$, can react with sodium hydroxide to form compounds **F**, **G** and **H**.

Compound **F**, $C_4H_{10}O$, exists as a pair of optical isomers. Compounds **G** and **H**, C_4H_8 , are structural isomers, and compound **H** exists as a pair of geometrical isomers.

(i) Draw the structures of the two optical isomers of **F**. *[2]*

(ii) Outline the use of a polarimeter in distinguishing between the optical isomers. *[2]*

(iii) Draw diagrams to show the shapes of the two geometrical isomers of **H**. *[2]*

(iv) Draw the mechanism, using curly arrows to represent the movement of electron pairs, to show the formation of **G**. *[3]*

(d) A compound, **J**, has the molecular formula $C_2H_4O_2$ and is obtained from a reaction between methanoic acid and methanol. Write an equation for this reaction and state the name of compound **J**. *[3]*

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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SPEC/4/CHEMI/HP2/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Higher Level

Paper 2

11 pages

SECTION A

1. (a) ΔT = 23.70-23.03 = 0.67 (^{o}C/K); ***[1]***

(b) $n = \left(\dfrac{0.4385 \text{ g}}{342.34 \text{ g mol}^{-1}} \right) = 1.281 \times 10^{-3} \text{ mol}$; ***[1]***

(c) (i) $\Delta H_c = (C\,\Delta T)/n = \dfrac{-(10.114 \text{ kJ K}^{-1})(0.67 \text{ K})}{(1.281 \times 10^{-3} \text{ mol})} = -5.3 \times 10^{3} \text{ kJ mol}^{-1}$; ***[1]***

Use ECF for values of ΔT *and n.*

(ii) Percentage experimental error = $\left[\dfrac{(-5.3 \times 10^{3}) + (5.6 \times 10^{3})}{(-5.6 \times 10^{3})} \right] \times 100 = 5.4\ \%$; ***[1]***

Use ECF for values of ΔH_c.

(d) enthalpy change of combustion of sucrose > TNT, and therefore not important;
rate of reaction for TNT is greater than that of sucrose, so this is valid;
amount of gas generated (in mol) for sucrose > than that of TNT (according to the given equation), so this is not important; ***[3]***

2. (a) (order with respect to) H_2 = 1;
(order with respect to) NO = 2; ***[2]***

(b) rate = $k[H_2]\,[NO]^2$; ***[1]***
ECF from (a).

(c) $(2.53 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1} = k(0.100 \text{ mol dm}^{-3})\,(0.100 \text{ mol dm}^{-3})^2)$
$k = 2.53 \times 10^{-3}$;
$\text{mol}^{-2}\ \text{dm}^{6}\ \text{s}^{-1}$; ***[2]***
ECF from (b).

(d) agrees / yes;

slow step depends on X and NO;
(so) NO is involved twice and H_2 once;
overall equation matches the stoichiometric equation / *OWTTE*;
ECF for "no", depending on answer for (b).

OR

agrees / yes;

and $\dfrac{[X]}{[H_2][NO]} = \text{constant}$;
rate of slow step = $k\,[X][NO]$;
but X depends on H_2 and NO;
rate of slow step = $k\,[H_2][NO]^2$; ***[4 max]***
*Award **[1]** each for any three of the four above.*
ECF for "no", depending on answer for (b).

(e) reaction involves <u>four</u> molecules;
statistically / geometrically unlikely; ***[2]***

(f) the rate of formation of H_2O = 2 × rate for N_2;
because 2 moles H_2O formed with 1 mole N_2 / *OWTTE*; ***[2]***

3. (a) Pt electrode;
1 mol dm^{-3} $[H^+(aq)]$;
H_2 gas;
at 1 atm / 1.01×10^5 Pa;
298 K / 25°C; ***[5]***
Accept suitable labelled diagram with the above.

(b) electron acceptor;
F_2 / fluorine; ***[2]***

(c) (i) (+)0.48 (V); ***[1]***

(ii) $Cu^{2+}(aq) + Sn(s) \rightarrow Sn^{2+}(aq) + Cu(s)$ ***[2]***
*Award **[1]** for correct reactants and products from (c)(i), and **[1]** for state symbols.*

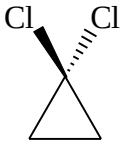
4. (a) (i) acidic **and** $[Fe(H_2O)_6]^{3+}$ is a weak acid
$[Fe(H_2O)_6]^{3+}(aq) \rightarrow [Fe(OH)(H_2O)_5]^{2+}(aq) + H^+(aq)$; ***[1]***
"$FeCl_3$ is acidic" is not acceptable.

(ii) neutral **and** $NaNO_3$ / sodium nitrate is formed from strong base and strong acid / ions do not hydrolyze; ***[1]***

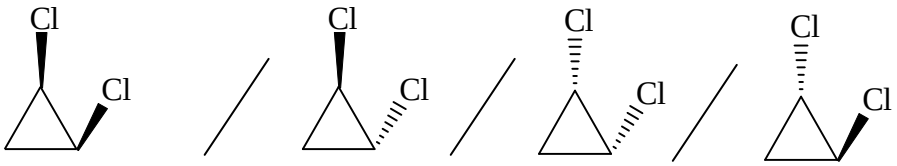
(iii) alkaline **and** CO_3^{2-} is a weak base / $CO_3^{2-}(aq) + H_2O(l) \rightarrow HCO_3^-(aq) + OH^-(aq)$; ***[1]***
*Award **[1]** only for correct identification of solutions as acidic, neutral and alkaline only, without explanation.*

(b) nitrogen **and** sulfur;
kills/harms fish/aquatic life in lakes/rivers;
leaching of soils damages plant life/trees; ***[3]***

5. (a)

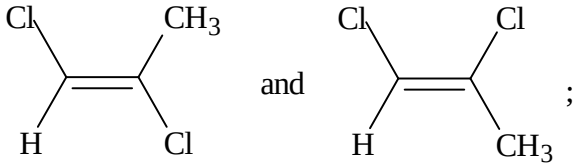


and 1,1 dichlorocyclopropane;

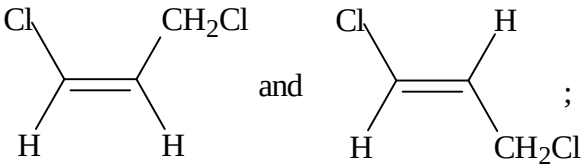


(*cis*-or *trans*-) 1,2 dichlorocyclopropane; ***[2]***
Award point for the correct name corresponding to the related isomer.
Accept diagrams that do not display 3 dimensional structure.
*Award **[1 max]** for correct structures only, without the corresponding names.*

(b)



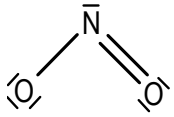
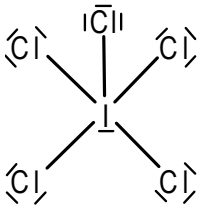
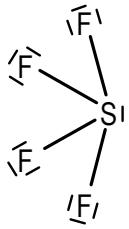
and ;



and ; ***[2]***

SECTION B

6. (a) (i)

Species	*Lewis (electron-dot) structure*	*Shape*	*Bond angle(s)*
NO_2^-	 ;	Bent/V-shaped/angular;	$109.5^o < \theta < 120^o$;
ICl_5	 ;	Square pyramidal;	|Inplane Cl-I-out-of-plane Cl| < 90^o; *Allow corresponding correct statement for other correctly identified bond angles.*
SF_4	 ;	See-saw;	|Equatorial F-S-Equatorial F| < 120^o; *Allow corresponding correct statement for axial-equatorial and axial-axial F-S-F angles.*

Accept crosses and dots for electrons in the Lewis structures also.
If all ideal bond angles are given, penalize once only.
As the Lewis structures were asked for, and not 3D representations, do not penalize incorrectly drawn geometries. ***[9]***

(ii) (equatorial F-S-equatorial F) less than 120^o since non-bonding electron pairs (exert greater repulsive forces and thus) compress the bond angles / *OWTTE;* ***[1]***

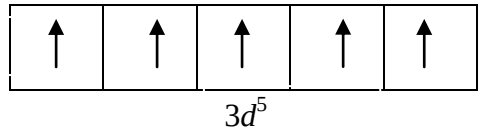
(iii) orbital diagram representation of carbon ground-state going to carbon excited-state electron configuration;
mixing of orbitals to give three new entirely equivalent hybrid orbitals, $\underline{sp^2}$ on each carbon;
sp^2 orbitals trigonal (triangular) planar in shape;
unhybridized orbitals overlap to give π-bond; ***[4]***

(iv) sp^2;
both N-O bond lengths equal, (intermediate between double and single bonds) due to <u>resonance/delocalisation</u>; ***[2]***

(v) O-H is most polar;
O-H has greatest difference between electronegativities / calculation showing values of 1.4, 0.5 and 0.9 respectively; ***[2]***

(b) (i) an ion or molecule, with a lone pair of electrons that coordinates to a metal atom or to a metal ion to form a complex / (*OWTTE*) **and** cyanide/ CN^- ; ***[1]***

(ii) $Fe^{3+} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$;



;

5 unpaired electrons; ***[3]***

(iii) presence of unpaired electrons;
the d orbitals are split into two energy levels;
electrons move between these energy levels;
absorb energy from light of visible wavelength / *OWTTE*; ***[3 max]***
*Award **[1]** each for any three.*

7. (a) $2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$;

Accept correct equation with NH_4OH instead of NH_3.

$n(H_2SO_4) = 0.0201 \times 0.150$ (mol);

$n(NH_3) = 6.03 \times 10^{-3}$ (mol);

$[NH_3] = 0.241$ (mol dm^{-3}); ***[4]***

*Award **[3]** for the correct final answer for the concentration calculation.*

(b) bromocresol green;
reaction of weak base and strong acid;
pH range of bromocresol green is 3.8 to 5.4 /occurs at pH < 7; ***[3]***

(c) (i) $K_b = 10^{-4.75} = 1.78 \times 10^{-5}$;

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$ / $[OH^-] = \sqrt{K_b[NH_3]}$;

$[OH^-] = \sqrt{1.78 \times 10^{-5} \times 0.121}$;

pOH = 2.83; ***[4]***

*Award **[4]** for the correct final answer.*
Allow ECF, for example any correct conversion of $[OH^-]$ to pOH.

(ii) a solution which resists change in pH / changes pH very slightly;
when <u>small</u> amounts of acid or base are added;
weak acid and its salt / weak acid and its conjugate base; ***[3]***

(iii) *$n(NH_3) = 0.00500$ (mol) **and** $n(HCl) = 0.00250$ (mol);*
$[NH_4^+] = [NH_3]$;

$[OH^-] = K_b = 1.78 \times 10^{-5}$;

(pOH = 4.75 so) pH = 9.25 *(allow 9.2 to 9.3)*; ***[4]***

*Award **[4]** for correct final answer.*
Accept other valid methods.

(d) (i) NaCl conducts **and** $SiCl_4$ does not;
NaCl ionic **and** $SiCl_4$ covalent;
<u>ions</u> can move in liquid (in NaCl); ***[3]***

(ii) NaCl pH = 7;
salt of strong acid and strong base / Na^+ and Cl^- not hydrolysed;
$SiCl_4$ pH = 0 to 3;
HCl is formed / strong acid formed; ***[4]***

8. (a) less product is present at higher temperatures;
therefore the forward reaction is exothermic; ***[2]***

(b) empirical formula = CN;
Working must be shown to get point.
$M_r = 50.9 \text{ (g mol}^{-1}\text{)}$;
$:\text{N}\equiv\text{C}-\text{C}\equiv\text{N}:$; ***[3]***

(c) (i) fertilizers / increasing crop yields;
production of explosives for mining; ***[1 max]***

(ii) $\Delta H =$ (sum of energies of bonds broken) – (sum of energies of bonds formed);
Can be implied by working.
correct substitution of values and numbers of bonds broken;
correct substitution of values and numbers of bonds made;
$(\Delta H = (\text{N}\equiv\text{N}) + 3(\text{H}-\text{H}) - 6(\text{N}-\text{H}) = 944 + 3(436) - 6(388) =) - 76.0 \text{ (kJ)}$; ***[4]***
Allow ECF.
Do not penalize for SF or units.
*Award **[4]** for correct final answer.*

(iii) $(\Delta S^{\ominus}[2\times193] - [192 + 3\times131]) = -199 \text{ (J K}^{-1}\text{ mol}^{-1}\text{)}$;
Allow ECF.
four gaseous molecules generating two gaseous molecules / fewer molecules of gas; ***[2]***

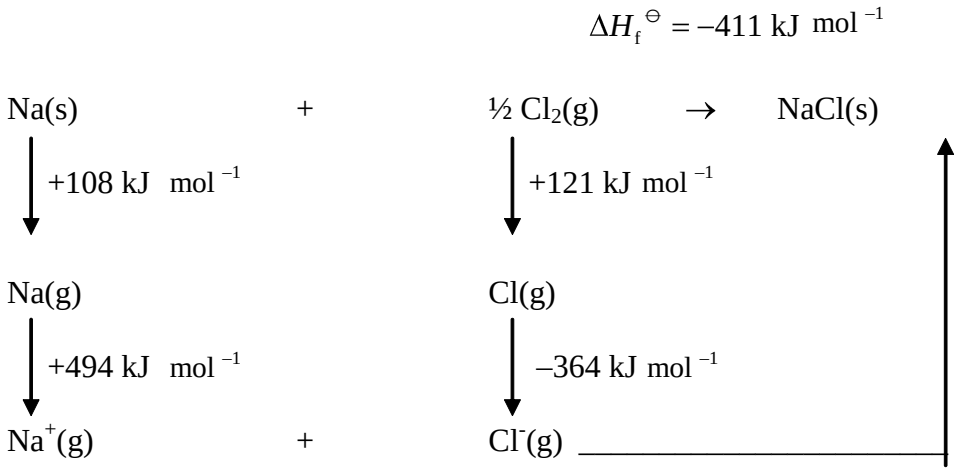
(iv) $(\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} = -76.0 - 298(-0.199)) = -16.7 \text{ (kJ)}$;
Spontaneous;
ΔG is negative; ***[3]***
Do not penalize for SF.

(v) heat released when gas → liquid;
$\Delta H^{\ominus}$ becomes more negative; ***[2]***

(d) (i) lattice enthalpy for a particular ionic compound is defined as ΔH for the process, $MX(s) \rightarrow M^+(g) + X^-(g)$;
Accept definition for exothermic process

electron affinity is the energy change that occurs when an electron is <u>added</u> to a <u>gaseous</u> atom or ion; ***[2]***

(ii)

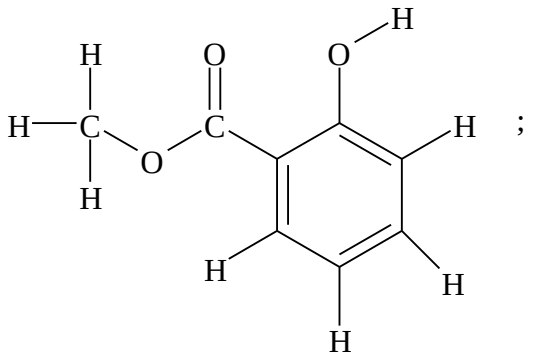


$$\text{lattice enthalpy} = -[(-411)-(+108)-(+494)-(+121)-(-364)] = 770 \text{ (kJ mol}^{-1}\text{)}$$

*Award **[2]** for all correct formulas in correct positions on cycle diagram.*
*1 incorrect or missing label award **[1]**.*
*Award **[1]** for all correct values in correct positions on cycle diagram.*
calculation of lattice enthalpy of NaCl(s) = 770 (kJ mol^{-1}); ***[4]***
Allow ECF.
Accept alternative method e.g. energy level diagram.

(iii) lattice/network/regular structure;
each chloride ion is surrounded by six sodium ions and each sodium ion is surrounded by six chloride ions/ 6:6 coordination; ***[2]***

9. (a) (i) (Empirical formula =) $C_8H_8O_3$;



;

[2]

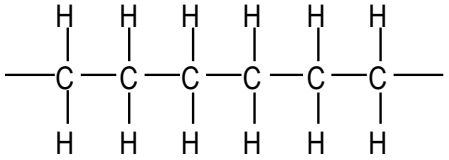
Allow double bonds on arene in alternate positions, or allow delocalized representation (of pi electrons).

(ii) the bond at <u>0.1373 nm</u> is a <u>double</u> bond **and** the bond at <u>0.1424 nm</u> is a <u>single</u> bond;
in $CO_2(g)$ both bonds are double bonds **and** would have a value around 0.137 nm; ***[2]***

(iii) ester;
arene / benzene ring;
alcohol; ***[2 max]***
*Award **[2]** for any three correct, award **[1]** for any two correct.*
Do not accept alkane as a type of functional group in this molecule.

(b) (i) A = $CH_3(CH_2)_7CHO$;
B = $CH_3(CH_2)_7COOH$ / $CH_3(CH_2)_7CO_2H$;
C = $(CH_3)_3COH$;
D = $(CH_3)_2CO$;
E = $BrCH_2CH_2Br$; ***[5]***
Allow correct structural formulas.

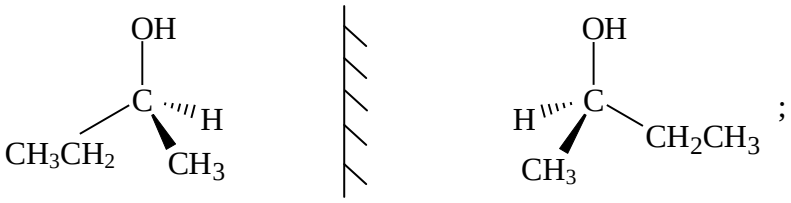
(ii) addition;



/ $-(CH_2-CH_2)_3-$ / $-(CH_2)_6-$;

[2]

(c) (i)

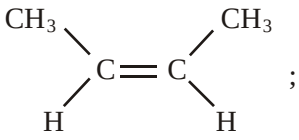


;

*Award **[2]** for both tetrahedral structures, or **[1]** if tetrahedral structure is not clear.* ***[2]***

(ii) plane polarized light;
rotation in opposite/different directions; ***[2]***

(iii)



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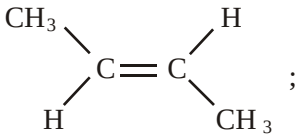


; ***[2]***

(iv) curly arrow showing attack by ^{-}OH on end H;
curly arrow showing C–Br bond fission;
curly arrow showing formation of double bond;
H_2O and Br^{-} shown as products; ***[3 max]***

*Award **[1]** each for any three.*
*If but-2-ene formed, award **[2 max]**.*

(d) $CH_3OH + HCOOH \rightarrow HCOOCH_3 + H_2O$

*Award **[1]** for both reactants and **[1]** for both products* (*accept* $C_2H_4O_2$).
methyl methanoate; ***[3]***

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

SPEC/4/CHEMI/HP3/ENG/TZ0/XX

CHEMISTRY
HIGHER LEVEL
PAPER 3

SPECIMEN PAPER

1 hour 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

Option A – Modern analytical chemistry

A1. Compounds **A** and **B** are alcohols with the molecular formula C_3H_8O. The following information was obtained from a mass spectrum of each alcohol.

A: peaks at *m/z* = 29, 31, 60

B: peaks at *m/z* = 45, 60

(a) Deduce the formula of the species responsible for the peak at *m/z* = 60. *[1]*

. . . . . .

(b) Deduce the formula of the species with *m/z* = 31. *[1]*

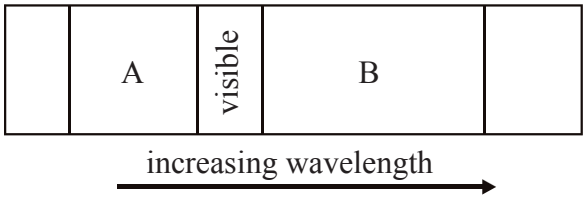
. . . . . .

(c) Deduce the structure of each alcohol. *[2]*

Structure of **A**

Structure of **B**

A2. The figure below shows the visible region of the electromagnetic spectrum and the two regions nearest to it.



(a) Name the regions labelled A and B, identify the atomic or molecular processes associated with each region and compare the energies of the radiation involved in these processes. *[5]*

Region A . . . . . .

. . . . . .

. . . . . .

. . . . . .

Region B . . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) State, giving a reason, which region (A or B) could be used to test for metal ions. *[1]*

. . . . . .

. . . . . .

A3. (a) State the main use of atomic absorption spectroscopy (AAS). *[1]*

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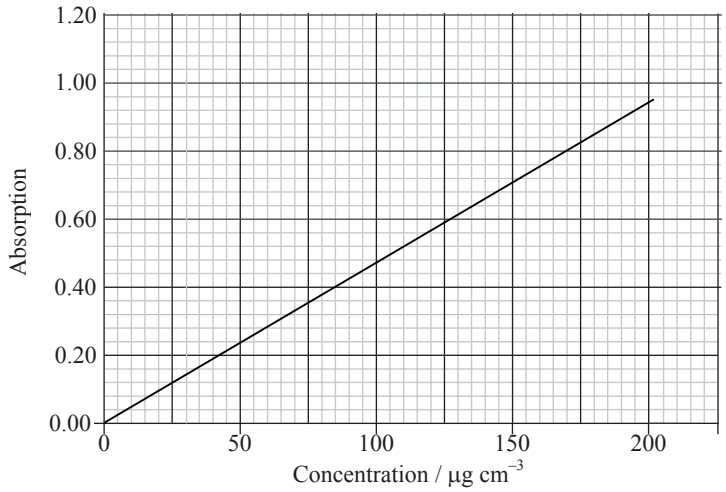
. . . . . .

(b) Ore samples may be analysed for iron using AAS. An ore sample was prepared in acid and diluted to 1 part in 10. The diluted solution gave an absorbance reading of 0.80. Determine the concentration of iron in the sample in mg cm^{-3}. *[2]*



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(c) Describe the use of each of the following components of the AA spectrophotometer. *[2]*

Atomizer

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. . . . . .

Monochromatic light source

. . . . . .

. . . . . .

A4. The colours of transition metal complexes depend on several factors.

(a) Use $[Mn(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{2+}$ as examples to outline why the colours depend on the identity of the transition metal. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Outline why the colour depends on the oxidation state of the transition metal. *[1]*

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A5. An analgesic tablet contains 400 mg of aspirin and 80 mg of caffeine. The molecular formula of aspirin is $C_9H_8O_4$ and that of caffeine is $C_8H_{10}N_4O_2$.

(a) State and explain which method, gas-liquid chromatography (GLC) or high performance liquid chromatography (HPLC), would be best for the separation and mass determination of aspirin and caffeine in the tablet. *[2]*

. . . . . .

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(b) State and explain which of the two components would have the shorter retention time. *[2]*

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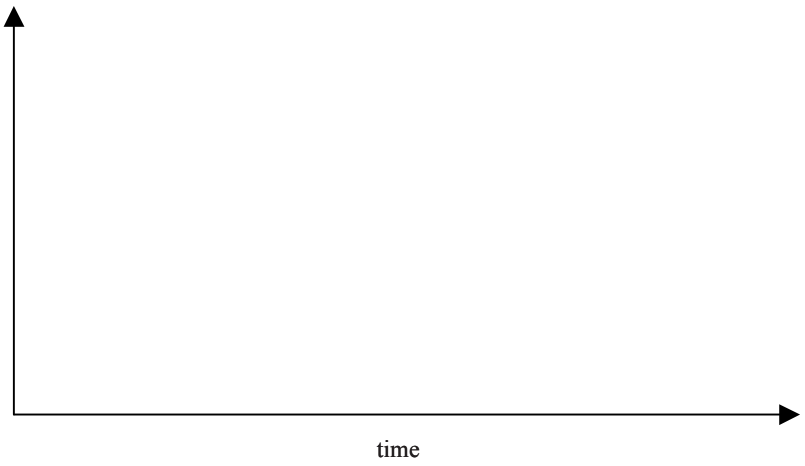
(c) Sketch a chromatograph for the separation of the aspirin and caffeine in the analgesic tablet. *[2]*



Option B – Human biochemistry

B1. (a) For each of the following vitamins describe its function in a diet and **one** effect of its deficiency. *[4]*

Vitamin C . . . . . .

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. . . . . .

. . . . . .

Vitamin D . . . . . .

. . . . . .

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(b) Discuss **two** solutions for the prevention of nutrient deficiencies. *[2]*

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B2. (a) State what is meant by *dietary fibre*. *[2]*

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. . . . . .
. . . . . .
. . . . . .

(b) Give **two** examples of dietary fibre. *[2]*

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. . . . . .

(c) Describe **two** reasons for the inclusion of dietary fibre in a healthy diet. *[2]*

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B3. (a) Compare the structural properties of starch and cellulose. *[4]*

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(b) Explain why humans cannot digest cellulose. *[1]*

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B4. Genetic information is stored in chromosomes which contain very long DNA sequences.

(a) A nucleotide of DNA contains deoxyribose, a phosphate group and an organic base. Outline how nucleotides are linked together to form polynucleotides. *[2]*

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(b) Describe the bonding between the two strands in the double helical structure of DNA. *[2]*

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B5. Describe aerobic respiration of glucose in the human body, with reference to oxidation and reduction. *[4]*

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Option C – Chemistry in industry and technology

C1. All methods of cracking use high temperatures, but the other conditions vary, depending on the types of product required.

(a) State the name of a catalyst used in catalytic cracking. Write an equation for the cracking of the straight-chain molecule $C_{14}H_{30}$ into **two** products, with equal chain length. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Name a substance, other than a catalyst, that is added to the feedstock to produce low molecular mass hydrocarbons and state **one** characteristic structural feature of the hydrocarbons produced. *[2]*

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. . . . . .

C2. List **two** factors to consider when choosing a catalyst for a process. *[2]*

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C3. Explain how a hydrogen-oxygen fuel cell works in an alkaline environment. Include relevant equations. *[5]*

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C4. (a) Define the term *nanotechnology*. *[3]*

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(b) Discuss **three** implications of the use of nanotechnology. *[3]*

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C5. (a) The manufacture of low density poly(ethene) is carried out at very high pressures and at a temperature of about 500 K. A catalyst (either an organic peroxide or a trace of oxygen) is added to the ethene. Explain how the catalyst reacts and write equations to show the mechanism of the polymerization. *[3]*

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(b) State the catalyst used to manufacture high density poly(ethene) and describe the feature of the catalyst that enables it to form intermediate complexes with the electrons of ethene molecules. *[2]*

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C6. Kevlar is a lyotropic liquid crystal.

(a) Explain why Kevlar is strong. *[1]*

. . . . . .

. . . . . .

(b) Explain why Kevlar is soluble in sulfuric acid. *[2]*

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Option D – Medicines and drugs

D1. One common type of medicine taken orally is an antacid. Antacids such as sodium hydrogencarbonate are taken to reduce stomach acidity.

(a) State the **names** of **two** metals, other than sodium, whose compounds are often used in antacids. *[1]*

. . . . . .

(b) Write an equation for the neutralization of hydrochloric acid in the stomach by sodium hydrogencarbonate. *[1]*

. . . . . .

(c) Explain how heartburn is caused. *[1]*

. . . . . .

. . . . . .

(d) Explain why dimethicone is added to some antacids. *[1]*

. . . . . .

. . . . . .

D2. (a) One method for detecting ethanol in breath involves blowing through a tube containing crystals of potassium dichromate(VI). The ethanol turns the crystals from orange to green. Explain what happens to both the dichromate(VI) ion and the ethanol in this reaction. *[2]*

. . . . . .

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(b) A modern method for accurately determining the amount of ethanol in breath uses an intoximeter. Describe how an intoximeter works. *[3]*

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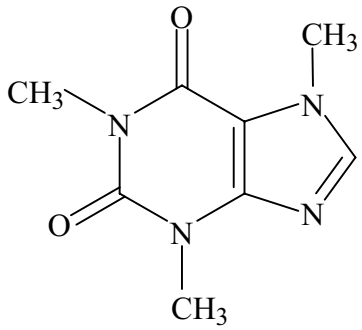
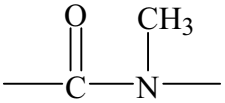
D3. Caffeine is a stimulant with the following structure.



Caffeine

(a) Determine whether both amine groups in caffeine are primary, secondary or tertiary. *[1]*

. . . . . .

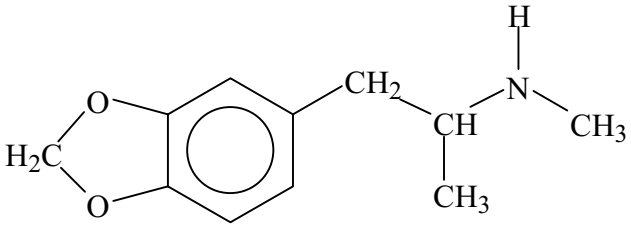
(b) Caffeine contains the group  . State the general name for this functional group. *[1]*

. . . . . .

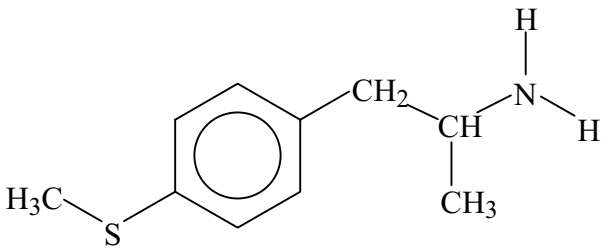
(This question continues on the following page)

(Question D3 continued)

(c) Tablets of the drug Ecstasy are sometimes contaminated with a substance called 4–MTA.



Ecstasy



4 – MTA

(i) Ecstasy and 4-MTA are sympathomimetic drugs. Identify the structural similarity between the two drugs and epinephrine (adrenaline), the structure of which is given in Table 20 of the Data Booklet. *[1]*

. . . . . .

. . . . . .

(ii) Outline what is meant by the term *sympathomimetic drug* and state **two** examples of short-term effects sympathomimetic drugs have on the human body. *[3]*

. . . . . .

. . . . . .

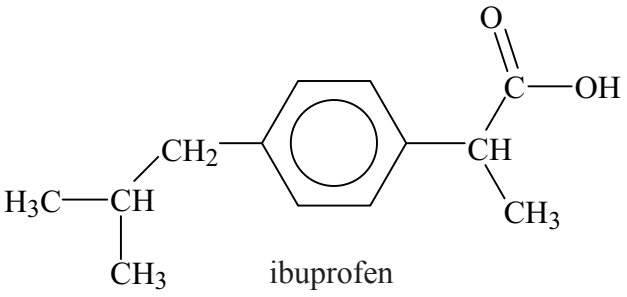
. . . . . .

. . . . . .

(iii) State **one** example of a long-term effect of taking stimulants. *[1]*

. . . . . .

D4. Ibuprofen is an analgesic with the following structure:



ibuprofen

(a) Identify the chiral carbon atom in the structure of ibuprofen using an asterisk (*). *[1]*

(b) Describe how chiral auxiliaries can be used to synthesize only the desired enantiomeric form of a drug from a non-chiral starting compound. Explain why it is important to use only the desired enantiomeric form of a drug and state an example of what can happen if a racemic mixture is used. *[5]*

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(c) Explain the importance of the beta-lactam ring action of penicillin. *[3]*

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Option E – Environmental chemistry

E1. The supply of sufficient drinking water continues to be a problem for the world. One method used to provide drinking water from seawater is reverse osmosis, which uses a partially permeable membrane.

(a) Outline the meanings of the terms *osmosis* and *partially permeable membrane*. *[2]*

Osmosis

. . . . . .

. . . . . .

Partially permeable membrane

. . . . . .

. . . . . .

(b) Explain the technique of reverse osmosis used to produce drinking water from seawater. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

E2. For each of the pollutants below, state **one** chemical method, different in each case, used to reduce the amount entering the atmosphere. Write **one** relevant equation relating to the chemistry behind the method.

(a) Carbon monoxide, CO *[2]*

. . . . . .

. . . . . .

(b) Sulfur(IV) oxide, SO_2 *[2]*

. . . . . .

. . . . . .

E3. (a) Explain, including an equation, why rain falling in unpolluted air is acidic with a pH of about 6. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Acid rain has a pH value less than 5.6. Explain, including an equation, how the burning of coal can contribute to acid rain formation. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) (i) Outline how acidic soil can damage the growth of trees. *[1]*

. . . . . .

. . . . . .

(ii) Write an equation for the reaction of acid rain on marble statues or limestone buildings. *[1]*

. . . . . .

(d) Explain how the addition of calcium oxide to lakes neutralizes the effects of acid rain. *[1]*

. . . . . .

. . . . . .

E4. (a) State and explain, using equations, the term *cation-exchange capacity* (CEC). *[4]*

. . . . . .

. . . . . .

. . . . . .

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. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Explain, using equations, how cation-exchange capacity is affected by acidic and basic soils. *[5]*

Acidic soils

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Basic soils

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option F – Food chemistry

F1. (a) (i) Explain the meaning of the term *shelf life*. *[1]*

. . . . . .

. . . . . .

(ii) State **two** properties which are affected when food has exceeded its shelf life. *[2]*

. . . . . .

. . . . . .

(b) Discuss **one** way, different in each case, in which each of the following factors affect the shelf life and quality of food: *[3]*

- water content
- pH change
- light.

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

F2. Compare the two processes of non-enzymatic browning (Maillard reaction) and caramelization that cause browning of food, in terms of the following.

(a) An example of **one** food affected *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(b) The chemical composition of food affected *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(c) The factors that increase the rate of browning *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(d) Features of the products *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

F3. Distinguish between the following types of dispersed systems. *[3]*

Suspension . . . . . .

. . . . . .

Emulsion. . . . . .

. . . . . .

Foam. . . . . .

. . . . . .

F4. Enantiomers are found in food.

(a) Distinguish between the two conventions, D / L and + (d) / – (l), used for naming enantiomers. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Identify the most common enantiomeric form of naturally occurring amino acids and describe their taste. *[2]*

. . . . . .

. . . . . .

. . . . . .

(c) Most naturally occurring sugars exist in the D form and are sweet. State an example of this. *[1]*

. . . . . .

. . . . . .

. . . . . .

(d) Define the term *racemic mixture*. *[1]*

. . . . . .

. . . . . .

(e) State **two** examples, other than taste, of properties of food that are affected by the presence of different enantiomers. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option G – Further organic chemistry

G1. When hydrogen cyanide reacts with an aldehyde or a ketone the product molecule has one more carbon atom.

(a) Write an equation to show the addition of hydrogen cyanide to propanone. *[1]*

. . . . . .

(b) Describe, using curly arrows, a mechanism for the reaction of hydrogen cyanide with propanone. *[4]*

(c) Write an equation for the acid hydrolysis of this product. State the **two** functional groups in the organic product. *[2]*

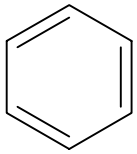
. . . . . .

. . . . . .

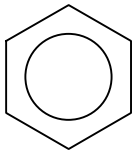
. . . . . .

. . . . . .

G2. The structure of benzene can be represented in two ways.



structure **A**



structure **B**

(a) Use information from Table 9 of the Data Booklet to explain why structure **B** is used in preference to structure **A**. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The enthalpy changes for the hydrogenation of cyclohexene and benzene are as follows.

$$C_6H_{10} + H_2 \rightarrow C_6H_{12} \qquad \Delta H^{\ominus} = -120 \text{ kJ mol}^{-1}$$

$$C_6H_6 + 3H_2 \rightarrow C_6H_{12} \qquad \Delta H^{\ominus} = -210 \text{ kJ mol}^{-1}$$

(i) Explain how this information can be used to support the statement that structure **B** is more stable than structure **A**. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) State what the circle in structure **B** represents. *[1]*

. . . . . .

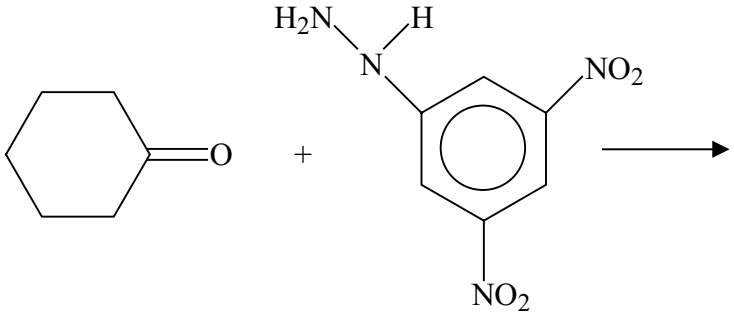
. . . . . .

G3. Cyclohexanone can react with 2,4-dinitrophenylhydrazine in aqueous solution.

(a) State the type of reaction that takes place. *[1]*

. . . . . .

(b) Complete the equation for this reaction using structural formulas for the products. *[2]*



(c) State why the product from this particular reaction can be used to confirm that the reactant was cyclohexanone and not any other carbonyl compound. *[1]*

. . . . . .

. . . . . .

G4. Explain how the presence of the $-NO_2$ group on a benzene ring affects the rate of further substitution. *[4]*

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G5. The compound CH_3CH_2COCl reacts rapidly with water. State the name of the organic product and write equations to show the mechanism of the reaction. *[5]*

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IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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SPEC/4/CHEMI/HP3/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Higher Level

Paper 3

15 pages

Option A – Modern analytical chemistry

A1. (a) $C_3H_8O^+$; ***[1]***
Accept more detailed formula such as $CH_3CH_2CH_2OH^+$.

(b) CH_3O^+ / CH_2OH^+; ***[1]***
For (a) and (b), if charge is missing penalize once only.

(c) (A) $CH_3CH_2CH_2OH$;
Accept more detailed formula.
(B) $CH_3CH(OH)CH_3$; ***[2]***
Accept more detailed formula.
Hydrogen(s) missing, penalize once only.
*Award **[1]** if both structures correct but the wrong way round.*

A2. (a) *Region A*
is the ultraviolet/UV;
electronic transitions;
Region B
is the infrared/IR;
molecular vibrations;
A is higher energy than B / *OWTTE*; ***[5]***
*If A and B the wrong way round **[3 max]**.*

(b) A (because) electron transitions occur; ***[1]***

A3. (a) measure low concentration of metals; ***[1]***

(b) absorbance reading of 0.80 = 170 μg cm^{-3};
(sample diluted by 10, therefore concentration of iron =
10×170 μg cm^{-3} = 1700 μg cm^{-3} =) 1.7 mg cm^{-3}; ***[2]***

(c) *Atomizer*
ions are converted / dissociated into atoms;
Monochromatic light source
Hollow cathode lamp specific to the element to be analysed; ***[2]***

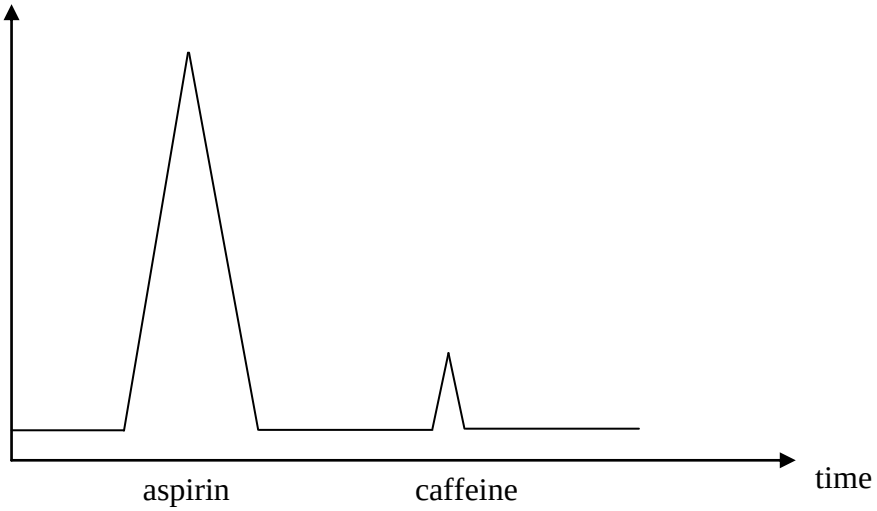
A4. (a) different metals cause the d orbitals to split differently due mainly to the different number of protons in the nucleus;
colour is caused by transitions between the d orbitals;
$[Mn(H_2O)_6]^{2+}$ is pink / colourless and $[Fe(H_2O)_6]^{2+}$ is green / the colours they show are complementary to the colours they absorb; ***[3]***

(b) the oxidation state affects the size of the d orbital splitting due to the different number of electrons present; ***[1]***

A5. (a) HPLC;
component would decompose (because of the higher temperature) in GLC; ***[2]***

(b) aspirin;
lower molecular mass; ***[2]***

(c)



relative position of peaks;
relative size of peaks; ***[2]***

Option B – Human biochemistry

B1. (a) *vitamin C function*
collagen formation / production of connective tissue / enhances absorption of iron (from food) / helps healing of wounds / can prevent bacterial infection / antioxidant / bone or teeth formation;
effects of deficiency
scorbutus / scurvy;
vitamin D function
uptake of calcium / phosphorus / bone or teeth formation;
effects of deficiency
rickets; ***[4]***

(b) *Any two of the following*:
providing food rations that are composed of fresh and vitamin– and mineral–rich foods;
adding nutrients missing in commonly consumed foods;
genetic modification of foods;
providing nutritional supplements; ***[2 max]***

B2. (a) plant material that is not hydrolysed by enzymes (secreted by the human digestive tract);
may be digested by microflora in the gut; ***[2]***

(b) *Any two of the following*:
cellulose;
hemicellulose;
lignin;
pectin; ***[2 max]***

(c) (may be helpful in the prevention of conditions/health problems such as)
Any two of the following:
diverticulosis;
irritable bowel syndrome;
constipation;
obesity;
Crohn's disease;
haemorrhoids;
diabetes mellitus; ***[2 max]***

B3. (a) both are polymers of glucose;
starch has two forms: amylose a straight chain polymer with α – 1, 4 linkages;
and amylopectin a branched polymer with α – 1, 4 and α – 1, 6 linkages;
cellulose has β – 1, 4 linkages; ***[4]***

(b) absence of cellulase enzyme; ***[1]***

B4. (a) the nucleotides condense / form a phosphodiester bond;
between the C_3 of the sugar and a neighbouring phosphate group; ***[2]***

(b) hydrogen bonds formed between the different strands;
thymine/T bonds to adenine/A and cytosine/C bonds to guanine/G; ***[2]***

B5. glucose is converted to pyruvate;
which in the presence of oxygen changes to carbon dioxide and water;
glucose undergoes oxidation;
oxygen undergoes reduction; ***[4]***

Option C – Chemistry in industry and technology

C1. (a) alumina / silica (*accept clay*) / aluminosilicates;
$C_{14}H_{30} \rightarrow C_7H_{14} + C_7H_{16}$; ***[2]***

(b) steam;
C=C / alkenes; ***[2]***

C2. *Any two of the following*:
selectivity/produce only the desired products;
efficiency;
ability to work under mild/severe conditions;
environmental impact;
problems caused by catalysts becoming poisoned by impurities;
cost; ***[2 max]***

C3. hydrogen and oxygen react to produce water / $2H_2(g) + O_2(g) \rightarrow 2H_2O$ (l);
porous electrodes allow the flow of oxygen, hydrogen and water;
(oxidation reaction/anode reaction:) $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O$ (l) $+ 2e^-$;
(reduction reaction/cathode reaction:) $O_2(g) + 2H_2O$ (l) $+ 4e^- \rightarrow 4OH^-(aq)$;
correct state symbols in last two equations; ***[5]***

C4. (a) nanotechnology involves the research and technology development at <u>1nm to 100 nm range</u>;
(nanotechnology) creates and uses structures that have novel properties because of their small size;
(nanotechnology) builds on the ability to control or manipulate at the atomic scale; ***[3]***

(b) *Any three of the following*:
toxicity regulations are difficult (to manage) as properties depend on size of particles;
unknown health effects, because new materials have new health risks;
concern that the human immune system will be defenceless against particles on the nanoscale;
responsibilities of industries;
political issues such as need for public education / informed debate / public involvement in policy discussions; ***[3 max]***

C5. (a) peroxide / oxygen acts as an initiator / to form free radicals / radical mechanism;

Any two correct equations:
$R{-}O{-}O{-}R \rightarrow 2\ RO\bullet$;
$RO\bullet + H_2C{=}CH_2 \rightarrow R{-}O{-}CH_2{-}CH_2\bullet$;
$R{-}O{-}CH_2{-}CH_2\bullet + H_2C{=}CH_2 \rightarrow R{-}O{-}CH_2{-}CH_2{-}CH_2{-}CH_2\bullet$; ***[3 max]***

(b) Ziegler-Natta catalyst / titanium(III) or titanium(IV) chloride (together with an alkyl-aluminium compound *e.g.* triethylaluminium $Al(C_2H_5)_3$);
the titanium atom can utilize its empty d orbitals; ***[2]***

C6. (a) hydrogen bonds / strong intermolecular forces; ***[1]***

(b) intermolecular forces can be broken by concentrated sulfuric acid;
as O and N atoms are protonated (breaking the hydrogen bonds); ***[2]***

Option D – Medicines and drugs

D1. (a) magnesium / aluminium / calcium; ***[1]***
*Any two for **[1]**.*

(b) $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$;
Do not allow H_2CO_3. ***[1]***

(c) acid from the stomach rises into the esophagus; ***[1]***

(d) as an anti-foaming agent / to prevent problem in (c) / to prevent flatulence; ***[1]***

D2. (a) the dichromate(VI) ion is reduced / forms the Cr^{3+} ion;
the ethanol is oxidized / forms ethanal / ethanoic acid; ***[2]***

(b) sample of breath passed into infrared spectrometer;
ethanol in breath absorbs because of C-H bond;
compares breath with air/reference sample with no ethanol; ***[3]***

D3. (a) tertiary; ***[1]***

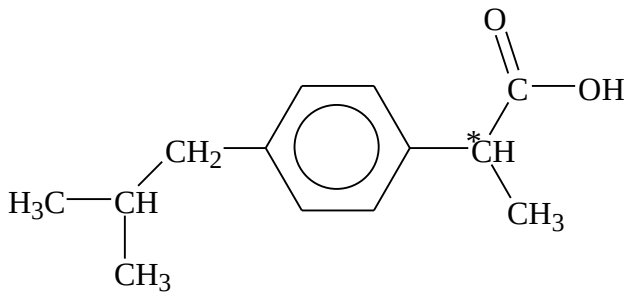
(b) amide; ***[1]***

(c) (i) all contain the phenylethylamine structure / contain an arene or benzene ring linked to two carbon atoms attached to an amine group; ***[1]***
Accept suitable diagram.

(ii) sympathomimetic drugs mimic the effect of adrenaline;
Any two of the following:
stimulate the sympathetic nervous system;
speed up the heart rate;
increase sweat production;
increase rate of breathing; ***[3 max]***

(iii) weight loss / constipation / emotional instability; ***[1]***

D4. (a)



[1]

(b) a chiral auxiliary is itself an enantiomer;
it is bonded to the reacting molecule to create the stereochemical conditions necessary to follow a certain pathway;
once the desired enantiomer is formed the auxiliary is removed;
different enantiomers may have different biological effects (some of which may be harmful);
genetic defects / deformities; ***[5]***

(c) the strain within the four-membered ring structure increases the reactivity of the amide;
the ring structure opens so that the penicillin becomes covalently bonded to the enzyme;
that synthesizes the bacterial cell walls (blocking its action); ***[3]***

Option E – Environmental chemistry

E1. (a) *osmosis*
movement of solvent / water from dilute to concentrated solution;
partially permeable membrane
allows solvent / water but not solute particles to pass through; ***[2]***

(b) pressure must be greater than osmotic pressure / 70 atm;
drinking / pure water passes through (partially permeable) membrane;
salt / dissolved solids left behind; ***[3]***

E2. (a) catalytic converter;
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$;

OR

thermal exhaust reactor;
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$; ***[2 max]***
Ignore state symbols.

(b) (alkaline) scrubbing / fluidised bed combustion;
$CaCO_3(s) + SO_2(g) \rightarrow CaSO_3(s) + CO_2(g)$ / $CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$; ***[2]***
Ignore state symbols.

E3. (a) it contains dissolved carbon dioxide / carbonic acid;
$CO_2(g) + H_2O(l) \rightarrow H^+(aq) + HCO_3^-(aq)$ / $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$; ***[2]***
Ignore state symbols.

(b) coal contains sulfur (which burns to form SO_2);
$S(s) + O_2(g) \rightarrow SO_2(g)$ / $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ /
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ / $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$; ***[2]***
Ignore state symbols.

(c) (i) *Any one of the following*:
it leaches nutrients / Ca^{2+} / Mg^{2+} / K^+ from the soil;
(it lowers the concentration of Mg^{2+} so) reduces the amount of chlorophyll / photosynthesis;
it increases the concentration of Al^{3+} (from rocks) which damages roots; ***[1 max]***

(ii) $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$; ***[1]***
Accept full equation with HNO_3, H_2SO_3 or H_2SO_4.
Ignore state symbols.

(d) CaO is a basic oxide / $CaO(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l)$; ***[1]***
Ignore state symbols.

E4. (a) CEC is a measure of the total number of sites available for cation exchange;
soils have (microscopic) clay particles with excess negative charges;

$$Clay^{-}(s) + M^{+}(aq) \rightarrow clay - M(s);$$

$$Clay - M(s) + M'^{+}(aq) \rightleftharpoons clay - M'(s) + M^{+}(aq);$$ ***[4]***

(b) *Acidic soils*
contain Fe^{3+} / Al^{3+};

$$clay - Al(s) + 4H_2O(l) \rightleftharpoons clay - H_3(s) + Al(OH)_4^{-}(aq) + H^{+}(aq);$$

a high proportion of cation exchange sites are occupied by H^{+} ions (which limits the availability of nutrient uptake);

Basic soils
contain Ca^{2+} / Mg^{2+} / K^{+};

$$clay - Ca(s) + 2H_2O(l) \rightleftharpoons clay - H_2(s) + Ca^{2+}(aq) + 2OH^{-}(aq);$$ ***[5]***

Option F – Food chemistry

F1. (a) (i) the period that maintains the expected quality desired by the consumer; ***[1]***

(ii) *Any two of the following*:
flavour;
smell;
texture;
colour;
mass; ***[2 max]***

(b) water content – loss of nutrients / browning / rancidity / microbial spoilage;
pH change – off flavours / colour change / browning / loss of nutrients;
light – rancidity / vitamin loss / fading of natural colours; ***[3]***

F2. (a) *Maillard*
Milk chocolate / toffees / caramels / fudges;
Caramelization
Roast potato skins / cola flavoured beverages / baked egg dishes; ***[2]***

(b) *Maillard*
An amino group **and** a reducing sugar;
Caramelization
High carbohydrate content; ***[2]***

(c) *Maillard*
Lysine browns most / cysteine browns least;
Caramelization
Acid / base catalysed / pH<3 / pH>9 / T>120ºC; ***[2]***

(d) *Maillard*
Desirable/undesirable colours / smells / flavours;
Caramelization
Caramel colour / aroma; ***[2]***

F3. (a) suspension – a mixture of a solid in a fluid;
emulsion – a mixture of 2 components which normally do not mix in which 1 component is distributed as droplets in the other;
foam – a mixture of 2 components which normally do not mix in which the dispersed component is gaseous; ***[3]***

F4. (a) *D and L* relates to the difference in spatial configuration of the enantiomers;
+(d) and –(l) relates to the direction of rotation of plane polarised light; ***[2]***

(b) L form;
tasteless; ***[2]***

(c) +(d)-limonene – oranges; ***[1]***

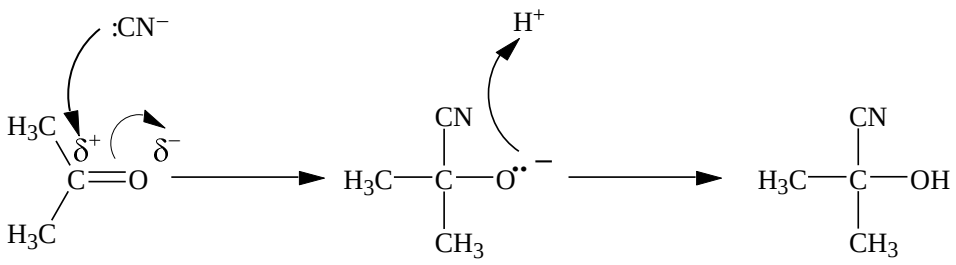
(d) a 50:50 composition / equal amounts of two enantiomers; ***[1]***

(e) odour;
toxicity; ***[2]***

Option G – Further organic chemistry

G1. (a) $(CH_3)_2CO + HCN \rightarrow (CH_3)_2C(OH)CN$; ***[1]***

(b)



Suitable diagram with

curly arrow showing attack by $:CN^-$ on carbonyl $C^{\delta+}$;
curly arrow showing pi bond breaking;
curly arrow from :O to H^+;
structure of product $(CH_3)_2C(OH)CN$; ***[4]***
Accept more detailed formula.

(c) $(CH_3)_2C(OH)CN + H^+ + 2H_2O \rightarrow (CH_3)_2C(OH)COOH + NH_4^+$;
carboxylic acid **and** alcohol; ***[2]***
Accept hydroxy(l) instead of alcohol.

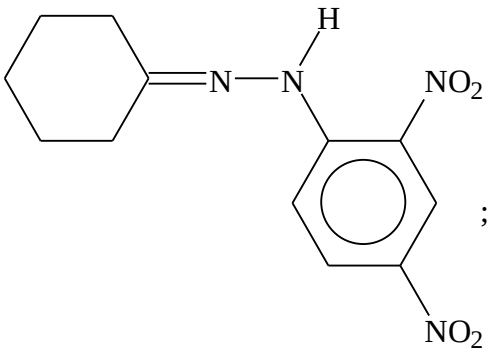
G2. (a) all C—C bonds in benzene or structure B are 0.139 (nm) (long) / the same length;
structure A would have C—C bond lengths of 0.154 and 0.134 (nm) / benzene does not have C—C bond lengths of 0.154 or 0.134 (nm) / different bond lengths; ***[2]***
*If no reference to carbon-carbon bonds, award **[1]**.*

(b) (i) structure A would have value of (about) –360 ($kJ\ mol^{-1}$);
150 ($kJ\ mol^{-1}$) / difference between –360 and –210 represents greater stability of benzene/structure B; ***[2]***

(ii) delocalized electrons; ***[1]***

G3. (a) addition-elimination / condensation; ***[1]***

(b)



; + H_2O ;

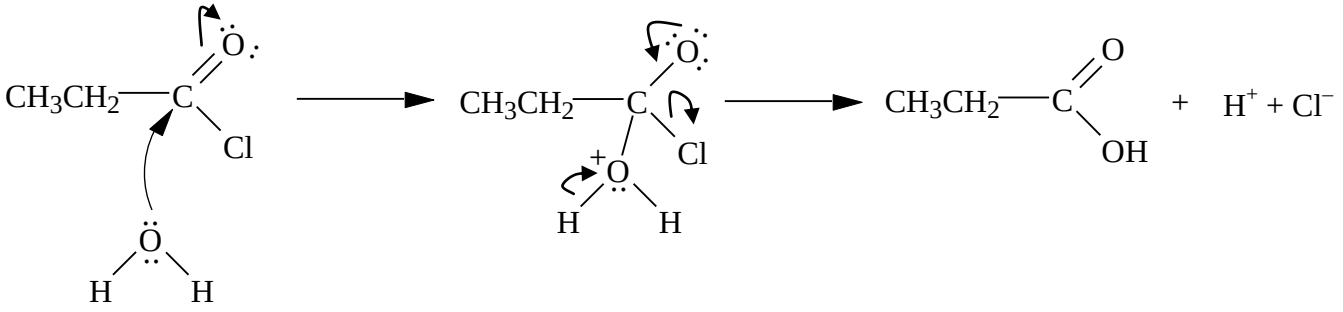
[2]

*Award **[1]** for correct structural formula of the organic product and **[1]** for water*.

(c) the (crystalline) solid has a characteristic melting point; ***[1]***

G4. $-NO_2$ is deactivating;
due to its overall electron withdrawing capacity;
which destabilises the carbocation intermediate;
and causes it to form more slowly; ***[4]***

G5. Propanoic acid;



Any four of the following:
curly arrow showing attack by H_2O / curly arrow showing C=O bond fission;
structure of intermediate including + and – charges;
curly arrow showing formation of C=O;
curly arrow showing loss of Cl^- / curly arrow showing loss of H^+;
both product formulas; ***[5 max]***

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

CHEMISTRY
STANDARD LEVEL
PAPER 1

SPECIMEN PAPER

45 minutes

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.

The Periodic Table

1	2											3	4	5	6	7	0
1 **H** 1.01				Atomic Number **Element** Atomic Mass													2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)															

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1. How many hydrogen atoms are in one mole of ethanol, C_2H_5OH?

A. 1.00×10^{23}

B. 3.61×10^{24}

C. 5.00

D. 6.00

2. What is the coefficient for $H_2SO_4(aq)$ when the following equation is balanced, using the smallest possible integers?

$$\_\_Mg_3N_2(s) + \_\_H_2SO_4(aq) \rightarrow \_\_MgSO_4(aq) + \_\_(NH_4)_2SO_4(aq)$$

A. 1

B. 3

C. 4

D. 7

3. Air bags in cars inflate when sodium azide decomposes to form sodium and nitrogen:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

Calculate the amount, in moles, of nitrogen gas produced by the decomposition of 2.52 mol of $NaN_3(s)$.

A. 1.68

B. 2.52

C. 3.78

D. 7.56

4. What volume, in cm^3, of 0.200 mol dm^{-3} HCl (aq) is required to neutralize 25.0 cm^3 of 0.200 mol dm^{-3} $Ba(OH)_2$(aq)?

A. 12.5

B. 25.0

C. 50.0

D. 75.0

5. Which species has 54 electrons and 52 protons?

A. $^{128}_{52}Te^{2-}$

B. $^{132}_{54}Xe^{2+}$

C. $^{132}_{54}Xe^{2-}$

D. $^{128}_{52}Te^{2+}$

6. What is the correct sequence for the processes occurring in a mass spectrometer?

A. vaporization, ionization, acceleration, deflection

B. vaporization, acceleration, ionization, deflection

C. ionization, vaporization, acceleration, deflection

D. ionization, vaporization, deflection, acceleration

7. Which series is arranged in order of **increasing** radius?

A. $Ca^{2+} < Cl^- < K^+$

B. $K^+ < Ca^{2+} < Cl^-$

C. $Ca^{2+} < K^+ < Cl^-$

D. $Cl^- < K^+ < Ca^{2+}$

8. What is the formula of the compound formed when aluminium reacts with oxygen?

A. Al_3O_2

B. Al_2O_3

C. AlO_2

D. AlO_3

9. Which statement is true for compounds containing only covalent bonds?

A. They are held together by electrostatic forces of attraction between oppositely charged ions.

B. They are made up of metal elements only.

C. They are made up of a metal from the far left of the periodic table and a non-metal from the far right of the periodic table.

D. They are made up of non-metal elements only.

10. How many electrons are used in the carbon-carbon bond in C_2H_2?

A. 4

B. 6

C. 10

D. 12

11. Which compound has the highest boiling point?

A. $CH_3CH_2CH_3$

B. CH_3CH_2OH

C. CH_3OCH_3

D. CH_3CHO

12. What type of solid materials are typically hard, have high melting points and poor electrical conductivities?

I. Ionic
II. Metallic
III. Covalent-network

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

13. How much energy, in joules, is required to increase the temperature of 2.0 g of aluminium from 25 to 30°C? (Specific heat of Al = 0.90 J g^{-1} K^{-1}).

A. 0.36

B. 4.5

C. 9.0

D. 54

14. Which combination is correct for a chemical reaction that absorbs heat from the surroundings?

	Type of reaction	**Δ*H* at constant pressure**
A.	Exothermic	Positive
B.	Exothermic	Negative
C.	Endothermic	Positive
D.	Endothermic	Negative

15. Using the equations below:

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -394 \text{ kJ mol}^{-1}$$

$$Mn(s) + O_2(g) \rightarrow MnO_2(s) \qquad \Delta H^{\ominus} = -520 \text{ kJ mol}^{-1}$$

What is ΔH, in kJ, for the following reaction?

$$MnO_2(s) + C(s) \rightarrow Mn(s) + CO_2(g)$$

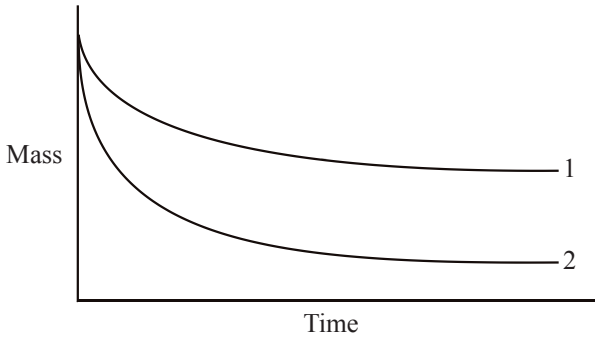
A. 914

B. 126

C. −126

D. −914

16. Excess magnesium, was added to a beaker of aqueous hydrochloric acid. A graph of the mass of the beaker and contents was plotted against time (line 1).



What change in the experiment could give line 2?

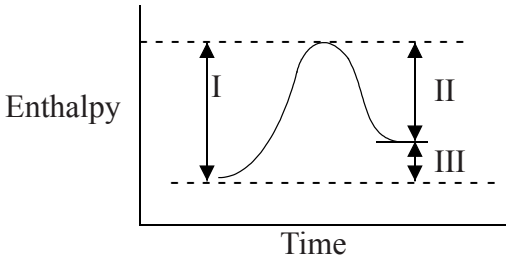
A. The same mass of magnesium in smaller pieces

B. The same volume of a more concentrated solution of hydrochloric acid

C. A lower temperature

D. A more accurate instrument to measure the time

17. Which quantities in the enthalpy level diagram are altered by the use of a catalyst?



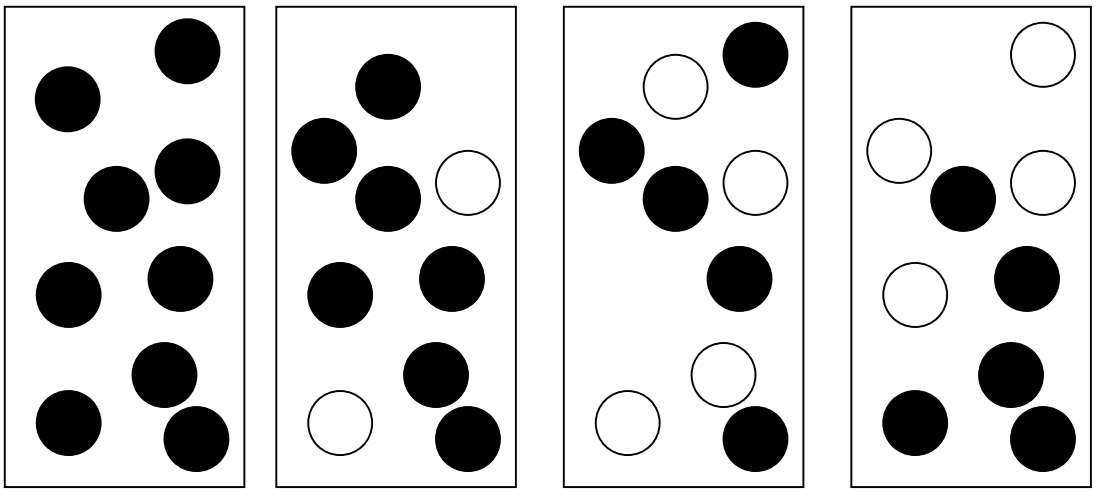
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18. The sequence of diagrams represents the system as time passes for a gas phase reaction in which reactant **X** is converted to product **Y**.



X = ●

Y = ○

Which statement is correct?

A. At $t = 5$ days the rate of the forward reaction is greater than the rate of the backward reaction.

B. At $t = 7$ seconds the reaction has reached completion.

C. At $t = 10$ minutes the system has reached a state of equilibrium.

D. At $t = 5$ days the rate of the forward reaction is less than the rate of the backward reaction.

19. What changes occur when the temperature is increased in the following reaction at equilibrium?

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad \Delta H^{\ominus} = +14 \text{ kJ mol}^{-1}$$

	Position of equilibrium	Value of equilibrium constant
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

20. Which species can act as a Lewis acid?

A. BF_3

B. OH^-

C. H_2O

D. NH_3

21. Which substance, when dissolved in water, to give a 0.1 mol dm^{-3} solution, has the highest pH?

A. HCl

B. NaCl

C. NH_3

D. NaOH

22. What is the reducing agent in this reaction?

$$Cu\,(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O\,(l)$$

A. Cu (s)

B. $NO_3^-(aq)$

C. $Cu^{2+}(aq)$

D. $H^+(aq)$

23. A particular voltaic cell is made from magnesium and iron half-cells. The overall equation for the reaction occurring in the cell is

$$Mg\,(s) + Fe^{2+}(aq) \rightarrow Mg^{2+}(aq) + Fe\,(s)$$

Which statement is correct when the cell produces electricity?

A. Magnesium atoms lose electrons.

B. The mass of the iron electrode decreases.

C. Electrons flow from the iron half-cell to the magnesium half-cell.

D. Negative ions flow through the salt bridge from the magnesium half-cell to the iron half-cell.

24. What process occurs at the cathode in a voltaic cell and at the anode in an electrolytic cell?

	Cathode of Voltaic cell	**Anode of Electrolytic cell**
A.	Oxidation	Reduction
B.	Oxidation	Oxidation
C.	Reduction	Oxidation
D.	Reduction	Reduction

25. Which statement about successive members of all homologous series is correct?

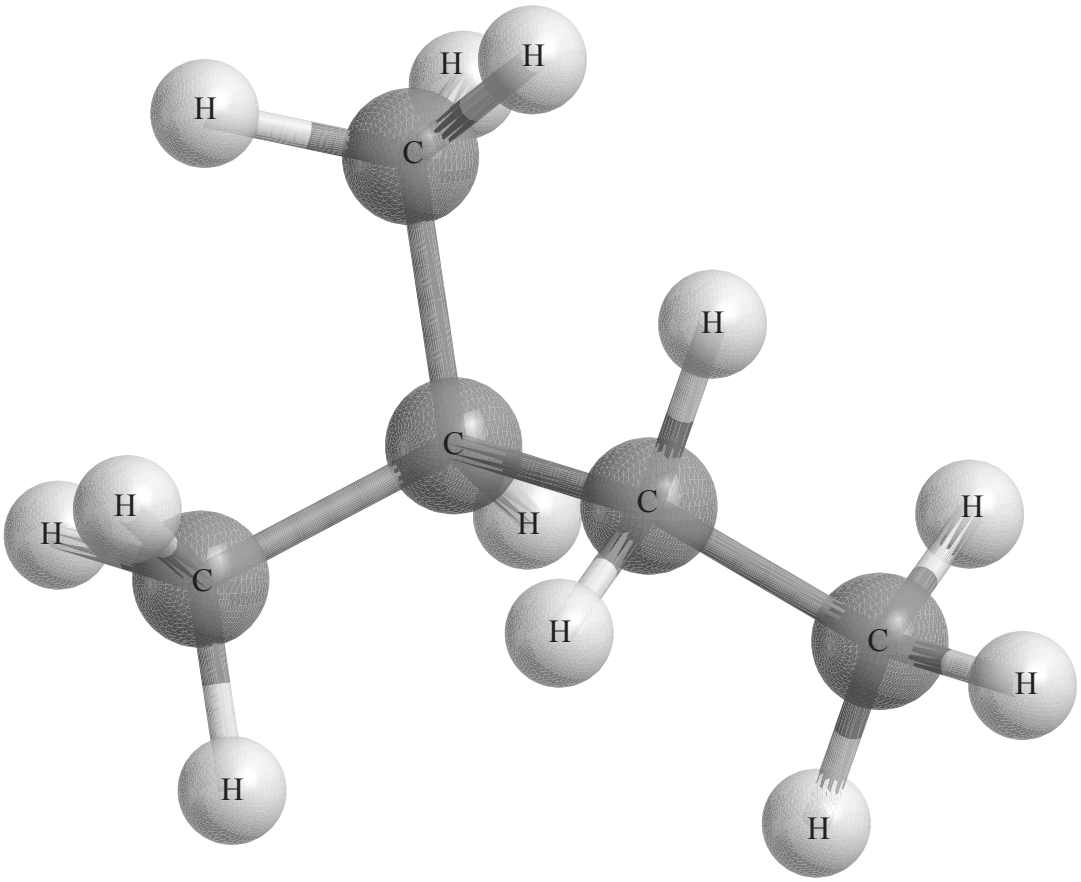
A. They have the same empirical formula.

B. They differ by a CH_2 group.

C. They have the same physical properties.

D. They differ in their degree of unsaturation.

26. The following is a three-dimensional representation of an organic molecule.



Which statement is correct?

A. The correct IUPAC name of the molecule is 2-methylpentane.

B. All the bond angles will be approximately 90°.

C. One isomer of this molecule is pentane.

D. The boiling point of this compound would be higher than that of pentane.

27. Which compound forms when hydrogen bromide is added to but-2-ene?

A. 2-bromobutane

B. 2,3-dibromobutane

C. 1-bromobutane

D. 1,2-dibromobutane

28. Which products can be potentially obtained from crude oil and are economically important?

I. Plastics
II. Margarine
III. Motor fuel

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. Propane, C_3H_8, undergoes incomplete combustion in a limited amount of air. Which products are most likely to be formed during this reaction?

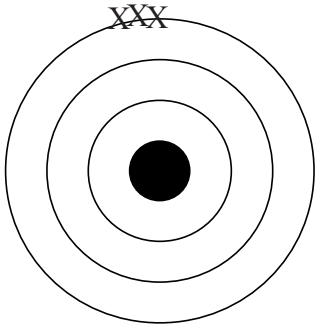
A. Carbon monoxide and water

B. Carbon monoxide and hydrogen

C. Carbon dioxide and hydrogen

D. Carbon dioxide and water

30. The following diagram shows a set of experimental data points, X, determined when one experimental measurement was repeated three times. The centre of the diagram represents the ideal value calculated from theory. What statement is correct about these measurements?



A. The measurements involve low accuracy and low precision.

B. The measurements involve low accuracy and high precision.

C. The measurements involve high accuracy and low precision.

D. The measurements involve high accuracy and high precision.

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

SPEC/4/CHEMI/SPM/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Standard Level

Paper 1

2 pages

1.	B	16.	B	31.	–	46.	–
2.	C	17.	A	32.	–	47.	–
3.	C	18.	C	33.	–	48.	–
4.	C	19.	D	34.	–	49.	–
5.	A	20.	A	35.	–	50.	–
6.	A	21.	D	36.	–	51.	–
7.	C	22.	A	37.	–	52.	–
8.	B	23.	A	38.	–	53.	–
9.	D	24.	C	39.	–	54.	–
10.	A	25.	B	40.	–	55.	–
11.	B	26.	C	41.	–	56.	–
12.	B	27.	A	42.	–	57.	–
13.	C	28.	B	43.	–	58.	–
14.	C	29.	A	44.	–	59.	–
15.	B	30.	B	45.	–	60.	–

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

CHEMISTRY
STANDARD LEVEL
PAPER 2

SPECIMEN PAPER

1 hour 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

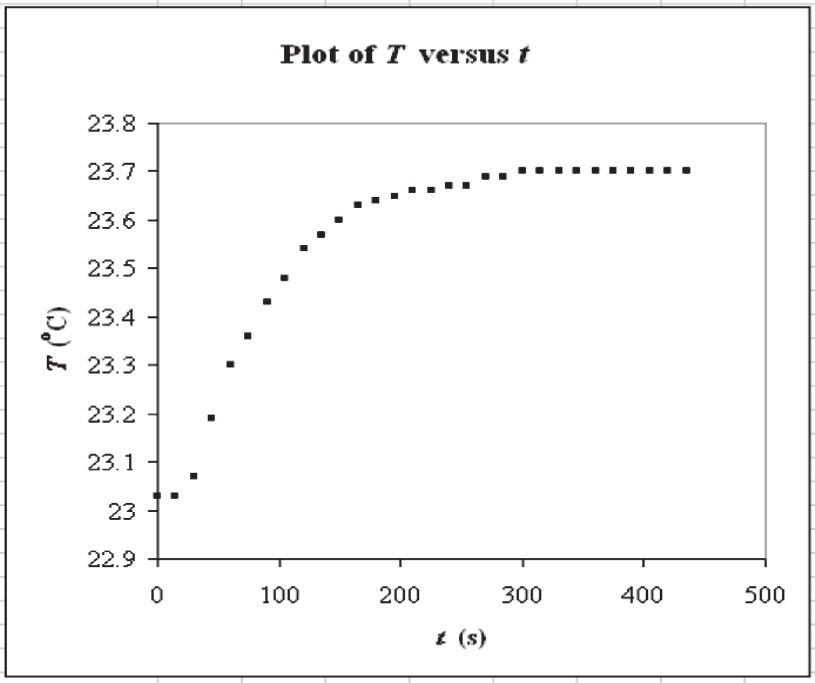
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer one question from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

SECTION A

*Answer **all** the questions in the spaces provided.*

1. The data below is from an experiment used to measure the enthalpy change for the combustion of 1 mole of sucrose (common table sugar), $C_{12}H_{22}O_{11}(s)$. The time-temperature data was taken from a data-logging software programme.

Time (s)	Temperature (°C)
0	23.03
15	23.03
30	23.07
45	23.19
60	23.3
75	23.36
90	23.43
105	23.48
120	23.54
135	23.57
150	23.6
165	23.63
180	23.64
195	23.65
210	23.66
225	23.66
240	23.67
255	23.67
270	23.69
285	23.69
300	23.7
315	23.7
330	23.7
345	23.7
360	23.7
375	23.7
390	23.7
405	23.7
420	23.7
435	23.7



Mass of sample of sucrose, $m = 0.4385$ g

Heat capacity of the system, $C_{system} = 10.114$ kJ K^{-1}

(a) Calculate ΔT, for the water, surrounding the chamber in the calorimeter. *[1]*

. . . . . .

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(b) Determine the amount, in moles, of sucrose. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(c) (i) Calculate the enthalpy change for the combustion of 1 mole of sucrose. *[1]*

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(ii) Using Table 12 of the Data Booklet, calculate the percentage experimental error based on the data used in this experiment. *[1]*

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(d) A hypothesis is suggested that TNT, 2-methyl-1,3,5-trinitrobenzene, is a powerful explosive because it has:

- a large enthalpy of combustion
- a high reaction rate
- a large volume of gas generated upon combustion

Use your answer in part (c)(i) and the following data to evaluate this hypothesis:

	Equation for combustion	**Relative rate of combustion**	**Enthalpy of combustion / kJ mol^{-1}**
Sucrose	$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(g)$	Low	
TNT	$2C_7H_5N_3O_6(s) \rightarrow 7CO(g) + 7C(s) + 5H_2O(g) + 3N_2(g)$	High	3406

[3]

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2. (a) List the following types of electromagnetic radiation in order of **increasing** wavelength (shortest first). *[1]*

I. Yellow light

II. Red light

III. Infrared radiation

IV. Ultraviolet radiation

. . . . . .

(b) Distinguish between a continuous spectrum and a line spectrum. *[1]*

. . . . . .

. . . . . .

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(c) The thinning of the ozone layer increases the amount of UV-B radiation that reaches the Earth's surface.

Type of Radiation	Wavelength / nm
UV-A	320 – 380
UV-B	290 – 320

Based on the information in the table above explain why UV-B rays are more dangerous than UV-A. *[3]*

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3. (a) Define the term *average bond enthalpy*. *[2]*

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(b) Use the information from Table 10 of the Data Booklet to calculate the enthalpy change for the complete combustion of but-1-ene, according to the following equation. *[3]*

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O\,(g)$$

. . . . . .

. . . . . .

. . . . . .

. . . . . .

4. 0.600 mol of aluminium hydroxide is mixed with 0.600 mol of sulfuric acid, and the following reaction occurs:

$$2Al(OH)_3(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 6H_2O\ (l)$$

(a) Determine the limiting reactant. *[2]*

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(b) Calculate the mass of $Al_2(SO_4)_3$ produced. *[2]*

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(c) Determine the amount (in mol) of excess reactant that remains. *[1]*

. . . . . .

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(d) Define a *Brønsted-Lowry acid* and a *Lewis base*. *[2]*

Brønsted-Lowry acid

. . . . . .

Lewis base

. . . . . .

(e) $H_2SO_4(aq)$ is a strong acid. State the name and the formula of any weak acid. *[1]*

. . . . . .

. . . . . .

5. (a) List **two** characteristics of a homologous series. *[1]*

. . . . . .

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(b) Ethanol and ethanoic acid can be distinguished by their melting points. State and explain which of the two compounds will have a higher melting point. *[2]*

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(c) Draw the **three** isomers containing the alcohol functional group of formula C_4H_9OH. *[2]*

SECTION B

*Answer **one** question. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

6. (a) (i) Outline the principles of the valence shell electron pair repulsion (VSEPR) theory. *[3]*

(ii) Use the VSEPR theory to deduce the shape of H_3O^+ and C_2H_4. For each species, draw the Lewis structure, name the shape, and state the value of the bond angle(s). *[6]*

(iii) Predict and explain whether each species is polar. *[2]*

(iv) Using Table 7 of the Data Booklet, predict and explain which of the bonds O-H, O-N or N-H would be most polar. *[2]*

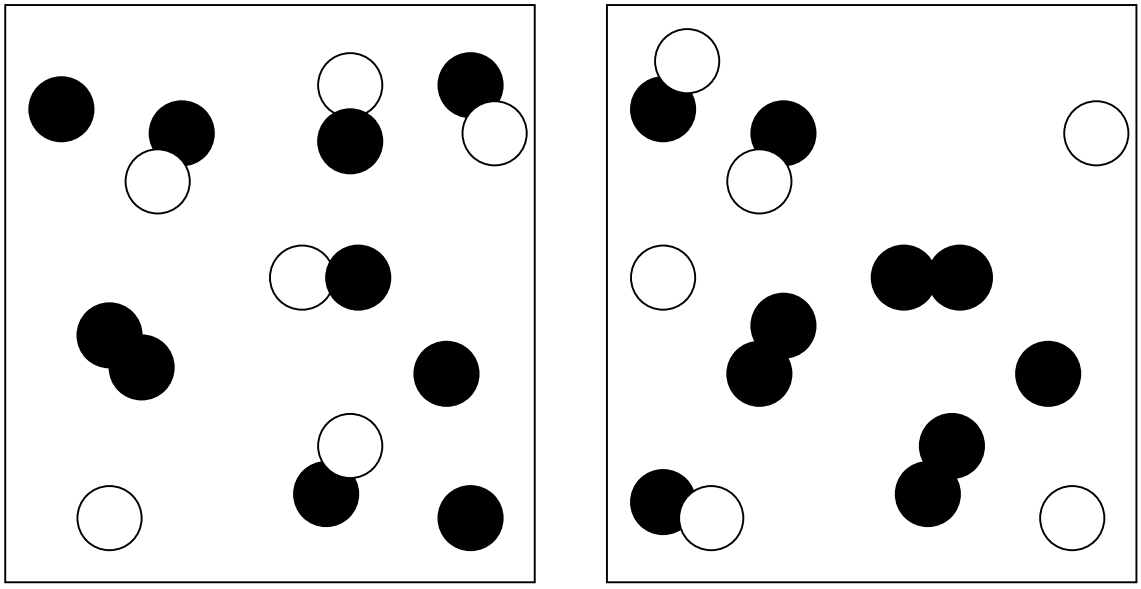
(b) Predict and explain which of the following compounds consist of molecules:
$NaCl$, BF_3, $CaCl_2$, N_2O, P_4O_6, FeS and CBr_4. *[2]*

(c) Diamond, graphite and C_{60} fullerene are three allotropes of carbon.

(i) Describe the structure of each allotrope. *[3]*

(ii) Compare the bonding in diamond and graphite. *[2]*

7. (a) The diagrams below represent equilibrium mixtures for the reaction $Y + X_2 \rightleftharpoons XY + X$ at 350 K and 550 K respectively. Deduce and explain whether the reaction is exothermic or endothermic. *[2]*



350 K 550 K

X = ●

Y = ○

(b) The equation for the main reaction in the Haber process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \text{ is negative}$$

(i) Determine the equilibrium constant expression for this reaction. *[1]*

(ii) State and explain the effect on the equilibrium yield of ammonia with increasing the pressure and the temperature. *[4]*

(iii) In practice, typical conditions used in the Haber process involve a temperature of 500 °C and a pressure of 200 atm. Explain why these conditions are used rather than those that give the highest yield. *[2]*

(iv) At a certain temperature and pressure, 1.1 dm^3 of $N_2(g)$ reacts with 3.3 dm^3 of $H_2(g)$. Calculate the volume of $NH_3(g)$, that will be produced. *[1]*

(v) Suggest why this reaction is important for humanity. *[1]*

(vi) A chemist claims to have developed a new catalyst for the Haber process, which increases the yield of ammonia. State the catalyst normally used for the Haber process, and comment on the claim made by this chemist. *[2]*

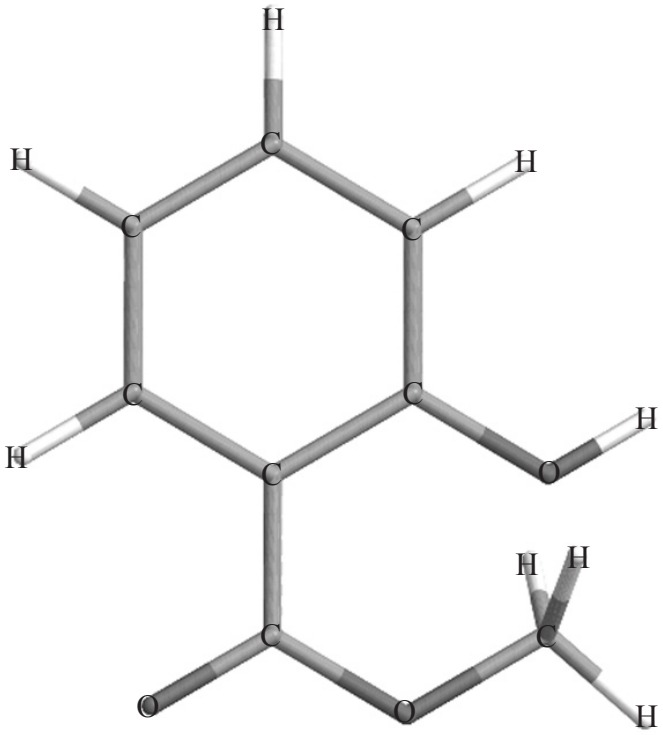
(This question continues on the following page)

(Question 7 continued)

(c) State **two** physical properties associated with metals and explain them at the atomic level. *[4]*

(d) Describe the acid-base character of the oxides of the period 3 elements Na to Ar. For sodium oxide and sulfur trioxide, write balanced equations to illustrate their acid-base character. *[3]*

8. (a) The following is a computer-generated representation of the molecule, methyl 2-hydroxy benzoate, better known as oil of wintergreen.



(i) Deduce the empirical formula of methyl 2-hydroxy benzoate and draw the full structural formula, including any multiple bonds that may be present. The computer-generated representation shown does not distinguish between single and multiple bonds. *[2]*

(ii) In this representation, two of the carbon-oxygen bond lengths shown are 0.1424 nm and 0.1373 nm. Explain why these are different and predict the carbon-oxygen bond length in carbon dioxide. *[2]*

(iii) Name all the functional groups present in the molecule. *[2]*

(b) (i) State and explain the trend in the boiling points of the first six alkanes involving straight-chains. *[2]*

(ii) Write an equation for the reaction between methane and chlorine to form chloromethane. Explain this reaction in terms of a free-radical mechanism. *[5]*

(This question continues on the following page)

(Question 8 continued)

(c) (i) Identify the formulas of the organic products, A-E, formed in the reactions, **I** – **IV**: *[5]*

I. $CH_3(CH_2)_8OH + K_2Cr_2O_7 \xrightarrow{H^+} \mathbf{A} \xrightarrow{H^+} \mathbf{B}$

II. $(CH_3)_3CBr + NaOH \longrightarrow \mathbf{C}$

III. $(CH_3)_2CHOH + K_2Cr_2O_7 \xrightarrow{H^+} \mathbf{D}$

IV. $H_2C{=}CH_2 + Br_2 \longrightarrow \mathbf{E}$

(ii) $H_2C{=}CH_2$ can react to form a polymer. Name this **type** of polymer and draw the structural formula of a section of this polymer consisting of three repeating units. *[2]*

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

SPEC/4/CHEMI/SP2/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Standard Level

Paper 2

9 pages

SECTION A

1. (a) ΔT = 23.70–23.03 = 0.67 (^{o}C/K); ***[1]***

(b) $n = \left(\frac{0.4385 \text{ g}}{342.34 \text{ g mol}^{-1}} \right) = 1.281 \times 10^{-3} \text{ mol}$; ***[1]***

(c) (i) $\Delta H_c = (C\,\Delta T)/n = \frac{-[(10.114 \text{ kJ K}^{-1})(0.67 \text{ K})]}{(1.281 \times 10^{-3} \text{ mol})} = -5.3 \times 10^{3} \text{ kJ mol}^{-1}$; ***[1]***

Use ECF for values of ΔT *and n.*

(ii) Percentage experimental error = $\left[\frac{(-5.3 \times 10^{3}) + (5.6 \times 10^{3})}{(-5.6 \times 10^{3})} \right] \times 100 = 5.4\ \%$; ***[1]***

Use ECF for values of ΔH_c.

(d) enthalpy change of combustion of sucrose > TNT, and therefore not important;
rate of reaction for TNT is greater than that of sucrose, so this is valid;
amount of gas generated (in mol) for sucrose > than that of TNT (according to the given equation), so this is not important; ***[3]***

2. (a) IV < I < II < III /ultra violet radiation < yellow light < red light < infrared radiation; ***[1]***

(b) A continuous spectrum has all colours/wavelengths/frequencies whereas a line spectrum has only (lines of) sharp/discrete/specific colours/ wavelengths/ frequencies; ***[1]***

(c) UV-B radiation has shorter wavelength;
hence, has higher energy;
increases risk of damage to skin cells / *OWTTE* / causes cancer; ***[3]***

3. (a) The amount of energy needed to break 1 mole of (covalent) bonds;
in the gaseous state;
average calculated from a range of compounds; ***[2 max]***
*Award **[1]** each for any two points above.*

(b) Bonds broken
$(612) + (2 \times 348) + (8 \times 412) + (6 \times 496) / 7580 \text{ (kJ mol}^{-1})$;
Bonds made
$(8 \times 743) + (8 \times 463) / 9648 \text{ (kJ mol}^{-1})$;
$\Delta H = -2068 \text{ (kJ mol}^{-1})$; ***[3]***
*Award **[3]** for the correct answer.*
Allow full ECF.
Allow kJ but no other incorrect units.
*Even if the first two marks are lost, the candidate can score **[1]** for a clear correct subtraction for* ΔH.

4. (a) 0.600 mol $Al(OH)_3 \equiv (1.5)(0.600)$ mol H_2SO_4 / 0.900 mol H_2SO_4 needed, but only 0.600 mol H_2SO_4 used;
H_2SO_4 limiting reactant; ***[2]***
Some working must be shown in order to score the second point.

(b) 0.200 mol $Al_2(SO_4)_3$;
68.4 (g); ***[2]***
Penalize incorrect units.

(c) 0.200 mol; ***[1]***
Use ECF from (a).

(d) A Brønsted Lowry acid is a proton/H^+ donor;
A Lewis base is an electron-pair donor; ***[2]***

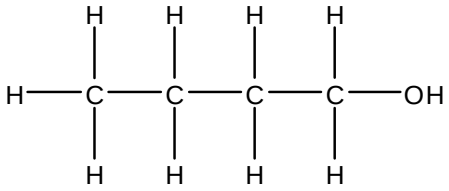
(e) H_2CO_3 and carbonic acid / CH_3COOH and ethanoic acid; ***[1]***
Accept any other weak acid and correct formula.

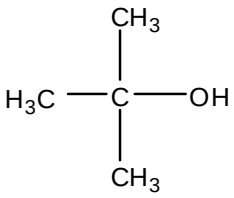
5. (a) one general formula / same general formula;
differ by CH_2 ;
similar chemical properties;
gradual change in physical properties; ***[1 max]***
*Award **[1]** for any two of the above characteristics.*

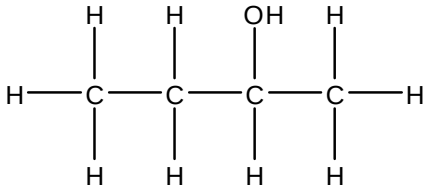
(b) ethanol lower / ethanoic acid higher;

due to larger mass of ethanoic acid / stronger van der Waals' / London / dispersion forces;
due to stronger hydrogen bonding / 2 hydrogen bonds per molecule; ***[2 max]***
Accept either answer for second mark.

(c)







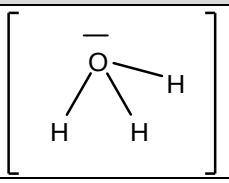
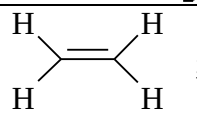
[2]
Allow condensed structural formulas such as $CH_3CH_2CH_2CH_2OH$.
*Award **[2]** for all three correct isomers, **[1]** for any two correct isomers.*

SECTION B

6. (a) (i) Find number of electron pairs/charge centres in (valence shell of) central atom;
electron pairs/charge centres (in valence shell) of central atom repel each other;

Any one of the following:
to positions of minimum energy/repulsion / maximum stability;
pairs forming a double or triple bond act as a single bond;
non-bonding pairs repel more than bonding pairs / *OWTTE*; ***[3 max]***
Do not accept repulsion between bonds or atoms.

(ii)

Species	Lewis (electron-dot) structure	Shape	Bond angle(s)
H_3O^+	 ;	Trigonal/triangular pyramidal;	Allow values in the range 106^o to 109.5^o;
C_2H_4	 ;	Trigonal/triangular planar;	Allow values of approximately 120^o;

Accept crosses and dots for electrons in Lewis structures also.
As the Lewis structures were asked for, and not 3D representations, do not penalize incorrectly drawn geometries.
Do not accept structure of hydronium cation without lone pair on oxygen.
No penalty for missing charge. ***[6]***

(iii) H_3O^+: is polar and explanation either using a diagram or in words, involving the net dipole moment;
e.g. the three individual O-H bond dipole moments add as vectors to give a net dipole moment.

C_2H_4: is non polar and explanation either using a diagram or in words, involving no net dipole moment; ***[2]***
e.g. the vector sum of the individual bond dipole moments is zero.

*For simple answers such as bond polarities do not cancel for H_3O^+ and do cancel for C_2H_4, Award **[1]**, only for the last two marking points.*

(iv) O-H is most polar;
O-H has greatest difference between electro negativities / calculation showing values of 1.4, 0.5 and 0.9 respectively; ***[2]***

(b) BF_3, N_2O, P_4O_6 and CBr_4;
Non-metals only / <u>small</u> difference in electronegativity values of the elements; ***[2]***

(c) (i)

Allotrope	Structure
Diamond	3D array/network involving tetrahedral carbons / each carbon atom joined to four others;
Graphite	layer structure involving trigonal (triangular) planar carbons / with each carbon atom joined to three others / with hexagonal (six-membered) rings of carbon atoms;
C_{60} fullerene	truncated icosahedrons; *Accept carbon atoms form a 'ball' with 32 faces, of which 12 are pentagons and 20 are hexagons, exactly like a soccer ball.* *Do not accept soccer ball alone.*

[3]

(ii) Diamond: covalent bonds (only);
Graphite: covalent bonds **and** the separated layers held together by (weak) London / van der Waals / dispersion forces; ***[2]***

7. (a) less product is present at higher temperatures;
Therefore the forward reaction is exothermic; ***[2]***

(b) (i) $(K_c=)\ \frac{[NH_3]^2}{[N_2][H_2]^3}$ *(ignore units)*; ***[1]***

(ii) *Increasing the pressure:*
Yield increases / equilibrium moves to the right / more ammonia;
4 gas molecules → 2 / decrease in volume / fewer gas molecules on right hand side;

Increasing the temperature:
Yield decreases / equilibrium moves to the left / less ammonia;
Exothermic reaction / *OWTTE*; ***[4]***

(iii) Higher temperature increases rate;
Lower pressure is less expensive / lower cost of operating at low pressure / reinforced pipes not needed; ***[2]***
Do not award a mark just for the word "compromise".

(iv) 2.2 (dm^3); ***[1]***
Penalize incorrect units.

(v) Fertilizers / increasing crop yields;
Production of explosives for mining; ***[1 max]***

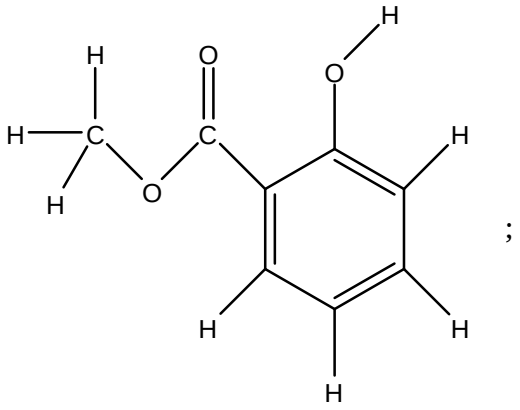
(vi) Fe/iron;
Allow magnetite/iron oxide.
Claim is not valid since catalysts do not alter the yield/position of equilibrium / only increase the rate of reaction; ***[2]***

(c) *Electrical conductivity:*
Bonding electrons are delocalised;
Current flow occurs without displacement of atoms within the metal / able to flow within the metal;

Malleability:
Can be hammered into thin sheets;
atoms capable of slipping with respect to one another; ***[4]***

(d) Oxides of: Na and Mg are basic;
Al is amphoteric;
Si to Cl are acidic;
Ar has no oxide;
*All four correct award **[2]**, two or three correct award **[1]**.*
$Na_2O + H_2O \rightarrow 2NaOH$ **and** $SO_3 + H_2O \rightarrow H_2SO_4$; ***[3]***
Must be balanced for mark.
Award marks for alternative correct equations such as SO_3 with NaOH.

8. (a) (i) (Empirical formula =) $C_8H_8O_3$;



; ***[2]***

Allow double bonds on arene in alternate positions, or allow delocalized representation (of pi electrons).

(ii) the bond at <u>0.1373 nm</u> is a <u>double</u> bond **and** the bond at <u>0.1424 nm</u> is a <u>single</u> bond;
in CO_2 (g) both bonds are double bonds **and** would have a value around 0.137 nm; ***[2]***

(iii) Ester;
Arene / benzene ring;
Alcohol; ***[2]***
*Award **[2]** for any three correct, award **[1]** for any two correct.*
Do not accept alkane as a type of functional group in this molecule.

(b) (i) boiling point increases as the number of carbons increases / *OWTTE*;
Greater M_r **and** hence greater van der Waals'/London/dispersion forces present; ***[2]***

(ii) $CH_4 + Cl_2 \xrightarrow{h\nu/\text{UV light}} CH_3Cl + HCl$;
Do not award mark if hv/uv light is not given.

Initiation step:
$Cl_2 \xrightarrow{h\nu/\text{UV light}} 2Cl\bullet$;
Do not award mark if hv/uv light is not given.
Penalize once only.

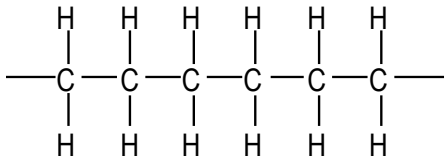
Propagation step:
$CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$;
$CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$;
Termination step:
$Cl\bullet + Cl\bullet \rightarrow Cl_2$ or $Cl\bullet + CH_3\bullet \rightarrow CH_3Cl$ or $CH_3\bullet + CH_3\bullet \rightarrow CH_3CH_3$; ***[5]***
Allow fish-hook half-arrow representations i.e. use of ↼.
Penalize use of full curly arrows once only.
Penalize missing dots on radicals once only.

(c) (i)

A. = $CH_3(CH_2)_7CHO$;
B. = $CH_3(CH_2)_7COOH$ / $CH_3(CH_2)_7CO_2H$;
C. = $(CH_3)_3COH$;
D. = $(CH_3)_2CO$;
E. = $BrCH_2CH_2Br$; ***[5]***

Allow correct structural formulas.

(ii) addition;



/ $-(CH_2-CH_2)_3-$ / $-(CH_2)_6-$; ***[2]***

IB DIPLOMA PROGRAMME
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SPEC/4/CHEMI/SP3/ENG/TZ0/XX

CHEMISTRY
STANDARD LEVEL
PAPER 3

SPECIMEN PAPER

1 hour

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

24 pages

Option A – Modern analytical chemistry

A1. Compounds **A** and **B** are alcohols with the molecular formula C_3H_8O. The following information was obtained from a mass spectrum of each alcohol.

A: peaks at *m/z* = 29, 31, 60

B: peaks at *m/z* = 45, 60

(a) Deduce the formula of the species responsible for the peak at *m/z* = 60. *[1]*

. . . . . .

(b) Deduce the formula of the species with *m/z* = 31. *[1]*

. . . . . .

(c) Deduce the structure of each alcohol. *[2]*

Structure of **A**

Structure of **B**

(This question continues on the following page)

(Question 1 continued)

(d) The ^{1}H NMR spectrum of one of the alcohols shows four peaks with areas in the ratio 3:2:2:1.

(i) State what can be deduced from this information. *[2]*

Four peaks

. . . . . .

. . . . . .

Areas in ratio 3:2:2:1

. . . . . .

. . . . . .

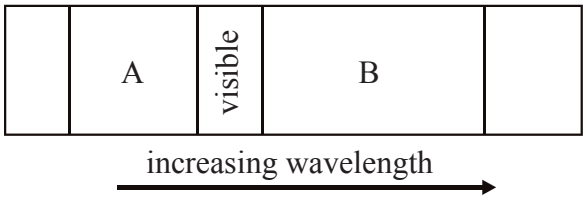
(ii) Predict the number of peaks, and the ratio of their areas, in the ^{1}H NMR spectrum of the other alcohol. *[2]*

. . . . . .

. . . . . .

. . . . . .

A2. The figure below shows the visible region of the electromagnetic spectrum and the two regions nearest to it.



(a) Name the regions labelled A and B, identify the atomic or molecular processes associated with each region and compare the energies of the radiation involved in these processes. *[5]*

Region A . . . . . .

. . . . . .

. . . . . .

. . . . . .

Region B . . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) State, giving a reason, which region (A or B) could be used to

(i) test for metal ions. *[1]*

. . . . . .

. . . . . .

(ii) obtain information about the types of bonds. *[1]*

. . . . . .

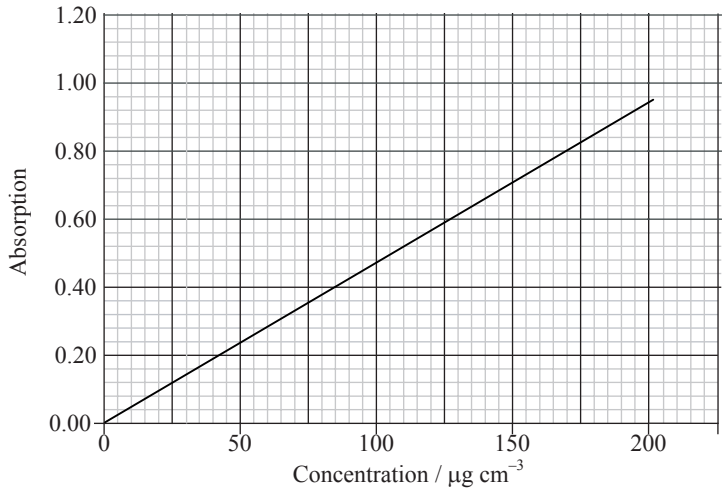
. . . . . .

A3. (a) State the main use of atomic absorption spectroscopy (AAS). *[1]*

. . . . . .

. . . . . .

(b) Ore samples may be analysed for iron using AAS. An ore sample was prepared in acid and diluted to 1 part in 10. The diluted solution gave an absorbance reading of 0.80. Determine the concentration of iron in the sample in mg cm^{-3}. *[2]*



. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Describe the use of each of the following components of the AA spectrophotometer. *[2]*

Atomizer

. . . . . .

. . . . . .

Monochromatic light source

. . . . . .

. . . . . .

Option B – Human biochemistry

B1. When many 2-amino acid molecules react together a protein is formed. These proteins have primary, secondary and tertiary structures.

(a) State the type of intermolecular force responsible for maintaining the secondary structure. *[1]*

. . . . . .

(b) Describe **two** other ways in which the tertiary structure of the protein is maintained. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

B2. (a) For each of the following vitamins describe its function in a diet and **one** effect of its deficiency. *[4]*

Vitamin C . . . . . .

. . . . . .

. . . . . .

. . . . . .

Vitamin D . . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Discuss **two** solutions for the prevention of nutrient deficiencies. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

B3. (a) State what is meant by *dietary fibre*. *[2]*

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. . . . . .

. . . . . .

. . . . . .

(b) Give **two** examples of dietary fibre. *[2]*

. . . . . .

. . . . . .

(c) Describe **two** reasons for the inclusion of dietary fibre in a healthy diet. *[2]*

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. . . . . .

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. . . . . .

B4. (a) Compare the structural properties of starch and cellulose. *[4]*

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. . . . . .

. . . . . .

. . . . . .

(b) Explain why humans cannot digest cellulose. *[1]*

. . . . . .

. . . . . .

Option C – Chemistry in industry and technology

C1. All methods of cracking use high temperatures, but the other conditions vary, depending on the types of product required.

(a) State the name of a catalyst used in catalytic cracking. Write an equation for the cracking of the straight-chain molecule $C_{14}H_{30}$ into **two** products, with equal chain length. *[2]*

. . . . . .

. . . . . .

. . . . . .

(b) Name a substance, other than a catalyst, that is added to the feedstock to produce low molecular mass hydrocarbons and state **one** characteristic structural feature of the hydrocarbons produced. *[2]*

. . . . . .

. . . . . .

. . . . . .

C2. List **two** factors to consider when choosing a catalyst for a process. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

C3. Explain how a hydrogen-oxygen fuel cell works in an alkaline environment. Include relevant equations. *[5]*

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C4. (a) Define the term *nanotechnology*. *[3]*

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. . . . . .

(b) Discuss **three** implications of the use of nanotechnology. *[3]*

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. . . . . .

C5. Describe the effects of tempering steel. *[3]*

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. . . . . .

. . . . . .

Option D – Medicines and drugs

D1. Many drugs are taken orally. State **three** other ways in which drugs may be taken by a patient. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

D2. One common type of medicine taken orally is an antacid. Antacids such as sodium hydrogencarbonate are taken to reduce stomach acidity.

(a) State the **names** of **two** metals, other than sodium, whose compounds are often used in antacids. *[1]*

. . . . . .

(b) Write an equation for the neutralization of hydrochloric acid in the stomach by sodium hydrogencarbonate. *[1]*

. . . . . .

(c) Explain how heartburn is caused. *[1]*

. . . . . .

. . . . . .

(d) Explain why dimethicone is added to some antacids. *[1]*

. . . . . .

. . . . . .

D3. (a) One method for detecting ethanol in breath involves blowing through a tube containing crystals of potassium dichromate(VI). The ethanol turns the crystals from orange to green. Explain what happens to both the dichromate(VI) ion and the ethanol in this reaction. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) A modern method for accurately determining the amount of ethanol in breath uses an intoximeter. Describe how an intoximeter works. *[3]*

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. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Suggest why it is advisable not to drink alcohol when taking other drugs. *[2]*

. . . . . .

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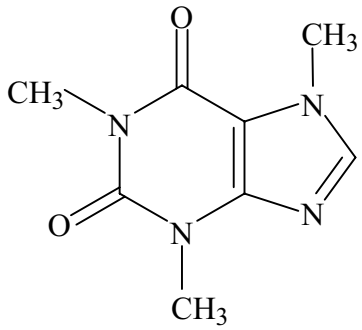
. . . . . .

. . . . . .

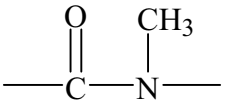
D4. Caffeine is a stimulant with the following structure.



Caffeine

(a) Determine whether both amine groups in caffeine are primary, secondary or tertiary. *[1]*

. . . . . .

(b) Caffeine contains the group 

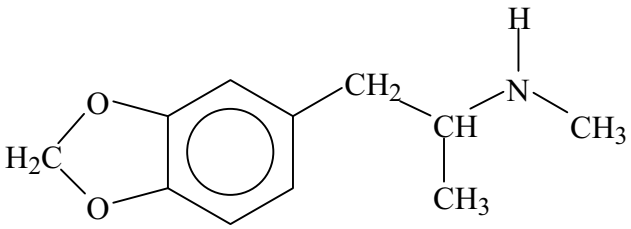
. State the general name for this functional group. *[1]*

. . . . . .

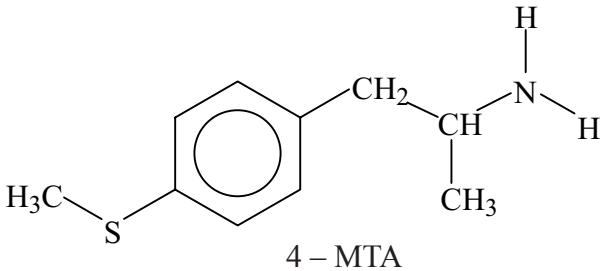
(This question continues on the following page)

(Question D4 continued)

(c) Tablets of the drug Ecstasy are sometimes contaminated with a substance called 4–MTA.



Ecstasy



4 – MTA

(i) Ecstasy and 4-MTA are sympathomimetic drugs. Identify the structural similarity between the two drugs and epinephrine (adrenaline), the structure of which is given in Table 20 of the Data Booklet. *[1]*

. . . . . .

. . . . . .

(ii) Outline what is meant by the term *sympathomimetic drug* and state **two** examples of short-term effects sympathomimetic drugs have on the human body. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) State **one** example of a long-term effect of taking stimulants. *[1]*

. . . . . .

Option E – Environmental chemistry

E1. The supply of sufficient drinking water continues to be a problem for the world. One method used to provide drinking water from seawater is reverse osmosis, which uses a partially permeable membrane.

(a) Outline the meanings of the terms *osmosis* and *partially permeable membrane*. *[2]*

Osmosis

. . . . . .

. . . . . .

Partially permeable membrane

. . . . . .

. . . . . .

(b) Explain the technique of reverse osmosis used to produce drinking water from seawater. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

E2. For each of the pollutants below, state **one** chemical method, different in each case, used to reduce the amount entering the atmosphere. Write **one** relevant equation relating to the chemistry behind the method.

(a) Carbon monoxide, CO *[2]*

. . . . . .

. . . . . .

(b) Nitrogen(II) oxide, NO *[2]*

. . . . . .

. . . . . .

(c) Sulfur(IV) oxide, SO_2 *[2]*

. . . . . .

. . . . . .

(d) Gasoline (petrol), C_8H_{18} *[2]*

. . . . . .

. . . . . .

E3. (a) Explain, including an equation, why rain falling in unpolluted air is acidic with a pH of about 6. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Acid rain has a pH value less than 5.6. Explain, including an equation, how the burning of coal can contribute to acid rain formation. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) (i) Outline how acidic soil can damage the growth of trees. *[1]*

. . . . . .

. . . . . .

(ii) Write an equation for the reaction of acid rain on marble statues or limestone buildings. *[1]*

. . . . . .

(d) Explain how the addition of calcium oxide to lakes neutralizes the effects of acid rain. *[1]*

. . . . . .

. . . . . .

Option F – Food chemistry

F1. (a) (i) Explain the meaning of the term *shelf life*. *[1]*

. . . . . .

. . . . . .

(ii) State **two** properties which are affected when food has exceeded its shelf life. *[2]*

. . . . . .

. . . . . .

(b) Discuss **one** way, different in each case, in which each of the following factors affect the shelf life and quality of food: *[3]*

- water content
- pH change
- light.

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

F2. Compare the two processes of non-enzymatic browning (Maillard reaction) and caramelization that cause browning of food, in terms of the following.

(a) An example of **one** food affected *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(b) The chemical composition of food affected *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(c) The factors that increase the rate of browning *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

(d) Features of the products *[2]*

Maillard reaction . . . . . .

. . . . . .

Caramelization . . . . . .

. . . . . .

F3. (a) Describe a dispersed system in food. *[1]*

. . . . . .

. . . . . .

(b) Distinguish between the following types of dispersed systems. *[3]*

Suspension . . . . . .

. . . . . .

Emulsion . . . . . .

. . . . . .

Foam . . . . . .

. . . . . .

(c) Lecithin is an example of a natural emulsifier. State **one** feature that enables lecithin to act as an emulsifier and describe its action. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option G – Further organic chemistry

G1. When hydrogen cyanide reacts with an aldehyde or a ketone the product molecule has one more carbon atom.

(a) Write an equation to show the addition of hydrogen cyanide to propanone. *[1]*

. . . . . .

(b) Describe, using curly arrows, a mechanism for the reaction of hydrogen cyanide with propanone. *[4]*

(c) Write an equation for the acid hydrolysis of this product. State the **two** functional groups in the organic product. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

G2. The pK_b values of some amines are shown in Table 15 of the Data Booklet. Write an equation for the reaction of ethylamine with water. State and explain how the basicity of ethylamine compares to that of ammonia. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

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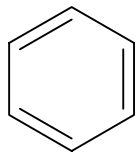
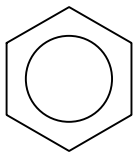
. . . . . .

. . . . . .

G3. The structure of benzene can be represented in two ways.



structure **A**



structure **B**

(a) Use information from Table 9 of the Data Booklet to explain why structure **B** is used in preference to structure **A**. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The enthalpy changes for the hydrogenation of cyclohexene and benzene are as follows.

$$C_6H_{10} + H_2 \rightarrow C_6H_{12} \qquad \Delta H^{\ominus} = -120 \text{ kJ mol}^{-1}$$

$$C_6H_6 + 3H_2 \rightarrow C_6H_{12} \qquad \Delta H^{\ominus} = -210 \text{ kJ mol}^{-1}$$

(i) Explain how this information can be used to support the statement that structure **B** is more stable than structure **A**. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) State what the circle in structure **B** represents. *[1]*

. . . . . .

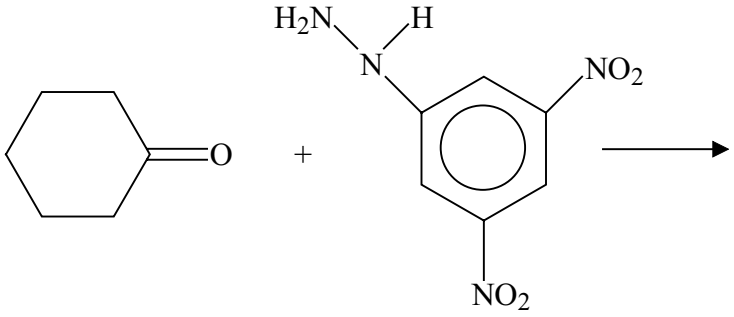
. . . . . .

G4. Cyclohexanone can react with 2,4-dinitrophenylhydrazine in aqueous solution.

(a) State the type of reaction that takes place. *[1]*

. . . . . .

(b) Complete the equation for this reaction using structural formulas for the products. *[2]*



(c) State why the product from this particular reaction can be used to confirm that the reactant was cyclohexanone and not any other carbonyl compound. *[1]*

. . . . . .

. . . . . .

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SPEC/4/CHEMI/SP3/ENG/TZ0/XX/M

MARKSCHEME

Specimen

CHEMISTRY

Standard Level

Paper 3

11 pages

Option A – Modern analytical chemistry

A1. (a) $C_3H_8O^+$; ***[1]***
Accept more detailed formula such as $CH_3CH_2CH_2OH^+$.

(b) CH_3O^+ / CH_2OH^+; ***[1]***
For (a) and (b), if charge is missing penalize once only.

(c) (A) $CH_3CH_2CH_2OH$;
Accept more detailed formula.
(B) $CH_3CH(OH)CH_3$; ***[2]***
Accept more detailed formula.
Hydrogen(s) missing, penalize once only.
*Award **[1]** if both structures correct but the wrong way round.*

(d) (i) (four) different environments for hydrogen atoms/protons;
the number of hydrogen atoms/protons in each environment
(are in the ratio 3:2:2:1); ***[2]***

(ii) 3 peaks;
6:1:1; ***[2]***
Order not important
*Award **[2]** for the ratio alone.*

A2. (a) *Region A*
is the ultraviolet/UV;
electronic transitions;
Region B
is the infrared/IR;
molecular vibrations;
A is higher energy than B /*OWTTE*; ***[5]***
*If A and B the wrong way round **[3 max]**.*

(b) (i) A (because) electron transitions occur; ***[1]***

(ii) B from vibration frequencies; ***[1]***
Allow ECF from (a).

A3. (a) measure low concentration of metals; ***[1]***

(b) absorbance reading of 0.80 = 170 μg cm^{-3};
(sample diluted by 10, therefore concentration of iron =
10 × 170 μg cm^{-3} = 1700 μg cm^{-3} =) 1.7 mg cm^{-3}; ***[2]***

(c) *Atomizer*:
ions are converted/dissociated into atoms;
Monochromatic light source:
Hollow cathode lamp specific to the element to be analysed; ***[2]***

Option B – Human biochemistry

B1. (a) hydrogen bonding; ***[1]***

(b) van der Waals' forces / hydrophobic interactions / London / dispersion forces;
ionic bonding / (formation of) salt bridges / electrostatic attractions;
covalent bonding / (formation of) disulfide bridges; ***[2 max]***
*Award **[1]** each for any two.*
Do not accept sulfur bridges or hydrogen bonding.

B2. (a) *vitamin C function*
collagen formation / production of connective tissue / enhances absorption of iron (from food) / helps healing of wounds / can prevent bacterial infection / antioxidant / bone or teeth formation;
effects of deficiency:
scorbutus / scurvy;
vitamin D function
uptake of calcium / phosphorus / bone or teeth formation;
effects of deficiency:
rickets; ***[4 max]***

(b) *Any two of the following*:
providing food rations that are composed of fresh and vitamin – and mineral – rich foods;
adding nutrients missing in commonly consumed foods;
genetic modification of foods;
providing nutritional supplements; ***[2 max]***

B3. (a) plant material that is not hydrolysed by enzymes (secreted by the human digestive tract);
may be digested by microflora in the gut; ***[2]***

(b) *Any two of the following*:
cellulose;
hemicellulose;
lignin;
pectin; ***[2 max]***

(c) (may be helpful in the prevention of conditions/health problems such as)
Any two of the following:
diverticulosis;
irritable bowel syndrome;
constipation;
obesity;
Crohn's disease;
haemorrhoids;
diabetes mellitus; ***[2 max]***

B4. (a) both are polymers of glucose;
starch has two forms: amylose a straight chain polymer with α – 1, 4 linkages;
and amylopectin a branched polymer with α – 1, 4 and α – 1, 6 linkages;
cellulose has β – 1, 4 linkages; ***[4]***

(b) absence of cellulase enzyme; ***[1]***

Option C – Chemistry in industry and technology

C1. (a) alumina / silica (*accept clay*) / aluminosilicates;
$C_{14}H_{30} \rightarrow C_7H_{14} + C_7H_{16}$; ***[2]***

(b) steam;
C=C / alkenes; ***[2]***

C2. *Any two of the following:*
selectivity/produce only the desired products;
efficiency;
ability to work under mild/severe conditions;
environmental impact;
problems caused by catalysts becoming poisoned by impurities;
cost; ***[2 max]***

C3. hydrogen and oxygen react to produce water / $2H_2(g) + O_2(g) \rightarrow 2H_2O\ (l)$;
porous electrodes allow the flow of oxygen, hydrogen and water;
(oxidation reaction/anode reaction) $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O\ (l) + 2e^-$;
(reduction reaction/cathode reaction) $O_2(g) + 2H_2O\ (l) + 4e^- \rightarrow 4OH^-(aq)$;
correct state symbols in last two equations; ***[5]***

C4. (a) nanotechnology involves the research and technology development at <u>1nm to 100 nm range</u>;
(nanotechnology) creates and uses structures that have novel properties because of their small size;
(nanotechnology) builds on the ability to control or manipulate at the atomic scale; ***[3]***

(b) *Any three of the following:*
toxicity regulations are difficult (to manage) as properties depend on size of particles;
unknown health effects, because new materials have new health risks;
concern that the human immune system will be defenceless against particles on the nanoscale;
responsibilities of industries;
political issues such as need for public education / informed debate / public involvement in policy discussions; ***[3 max]***

C5. steel becomes tough and springy;
internal stresses are removed;
replaces brittleness with toughness; ***[3]***

Option D – Medicines and drugs

D1. rectally / suppository;
inhalation;
injection / parenterally / intravenous / subcutaneous / intramuscular;
applying to skin / topically; ***[2 max]***
*Award **[2]** for three, **[1]** for two.*

D2. (a) magnesium / aluminium / calcium; ***[1]***
*Any two for **[1]**.*

(b) $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$; ***[1]***
Do not allow H_2CO_3.

(c) acid from the stomach rises into the esophagus; ***[1]***

(d) as an anti-foaming agent / to prevent problem in (c) / to prevent flatulence; ***[1]***

D3. (a) the dichromate(VI) ion is reduced / forms the Cr^{3+} ion;
the ethanol is oxidized / forms ethanal / ethanoic acid; ***[2]***

(b) sample of breath passed into infrared spectrometer;
ethanol in breath absorbs because of C-H bond;
compares breath with air/reference sample with no ethanol; ***[3]***

(c) *Any two of the following*:
alcohol has a synergistic effect with other drugs;
alcohol depresses central nervous system which alters the effect of other drugs;
increased risk of stomach bleeding with aspirin; ***[2 max]***

D4. (a) tertiary; ***[1]***

(b) amide; ***[1]***

(c) (i) all contain the phenylethylamine structure / contain an arene or benzene ring linked to two carbon atoms attached to an amine group; ***[1]***
Accept suitable diagram.

(ii) sympathomimetic drugs mimic the effect of epinephine/adreneline;
Any two of the following:
stimulate the sympathetic nervous system;
speed up the heart rate;
increase sweat production;
increase rate of breathing; ***[3 max]***

(iii) weight loss / constipation / emotional instability; ***[1]***

Option E – Environmental chemistry

E1. (a) *osmosis*
movement of solvent / water from dilute to concentrated solution;
partially permeable membrane
allows solvent / water but not solute particles to pass through; ***[2]***

(b) pressure must be greater than osmotic pressure / 70 atm;
drinking / pure water passes through (partially permeable) membrane;
salt / dissolved solids left behind; ***[3]***

E2. (a) catalytic converter;
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$;

OR

thermal exhaust reactor;
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$; ***[2 max]***
Ignore state symbols.

(b) catalytic converter / lean burn engine;
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$; ***[2]***
Ignore state symbols.

(c) (alkaline) scrubbing / fluidised bed combustion;
$CaCO_3(s) + SO_2(g) \rightarrow CaSO_3(s) + CO_2(g) / CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$; ***[2]***
Ignore state symbols.

(d) catalytic converter / thermal exhaust reactor;
$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$; ***[2]***
Ignore state symbols.

E3. (a) it contains dissolved carbon dioxide / carbonic acid;
$CO_2(g) + H_2O(l) \rightarrow H^+(aq) + HCO_3^-(aq)$ / $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$; ***[2]***
Ignore state symbols.

(b) coal contains sulfur (which burns to form SO_2);
$S(s) + O_2(g) \rightarrow SO_2(g)$ / $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ /
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ / $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$; ***[2]***
Ignore state symbols.

(c) (i) *Any one of the following*:
it leaches nutrients / Ca^{2+} / Mg^{2+} / K^+ from the soil;
(it lowers the concentration of Mg^{2+} so) reduces the amount of chlorophyll / photosynthesis;
it increases the concentration of Al^{3+} (from rocks) which damages roots; ***[1 max]***

(ii) $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$; ***[1]***
Accept full equation with HNO_3, H_2SO_3 or H_2SO_4.
Ignore state symbols.

(d) CaO is a basic oxide / $CaO(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l)$; ***[1]***
Ignore state symbols.

Option F – Food chemistry

F1. (a) (i) the period that maintains the expected quality desired by the consumer; ***[1]***

(ii) *Any two of the following*:
flavour;
smell;
texture;
colour;
mass; ***[2 max]***

(b) water content – loss of nutrients / browning / rancidity / microbial spoilage;
pH change – off flavours / colour change / browning / loss of nutrients;
light – rancidity / vitamin loss / fading of natural colours; ***[3]***

F2. (a) *Maillard*
Milk chocolate / toffees / caramels / fudges;
Caramelization
Roast potato skins / cola flavoured beverages / baked egg dishes; ***[2]***

(b) *Maillard*
An amino group **and** a reducing sugar;
Caramelization
High carbohydrate content; ***[2]***

(c) *Maillard*
Lysine browns most / cysteine browns least;
Caramelization
Acid / base catalysed / pH<3 / pH>9 / T>120ºC; ***[2]***

(d) *Maillard*
Desirable/undesirable colours / smells / flavours;
Caramelization
Caramel colour / aroma; ***[2]***

F3. (a) a kinetically stable mixture of one phase in another largely immiscible phase; ***[1]***

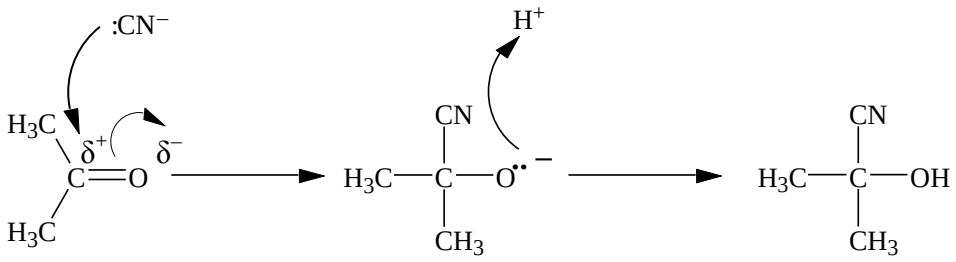
(b) suspension – a mixture of a solid in a fluid;
emulsion – a mixture of 2 components which normally do not mix in which 1 component is distributed as droplets in the other;
foam – a mixture of 2 components which normally do not mix in which the dispersed component is gaseous; ***[3]***

(c) contains hydrophobic and hydrophilic groups / soluble in fats/oils and water;
acts as an interface between the fat/oil and water; ***[2]***

Option G – Further organic chemistry

G1. (a) $(CH_3)_2CO + HCN \rightarrow (CH_3)_2C(OH)CN$; ***[1]***

(b)



Suitable diagram with

curly arrow showing attack by $:CN^-$ on carbonyl $C^{\delta+}$;
curly arrow showing pi bond breaking;
curly arrow from :O to H^+;
structure of product $(CH_3)_2C(OH)CN$; ***[4]***
Accept more detailed formula.

(c) $(CH_3)_2C(OH)CN + H^+ + 2H_2O \rightarrow (CH_3)_2C(OH)COOH + NH_4^+$;
carboxylic acid **and** alcohol; ***[2]***
Accept hydroxy(l) instead of alcohol.

G2. $CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ + OH^-$;
(ethylamine) more basic / higher basicity / lower pK_b;
because of presence of electron-releasing (ethyl or alkyl) group / N more electron-rich;
attracts H^+ (or H from H_2O) more easily; ***[4]***

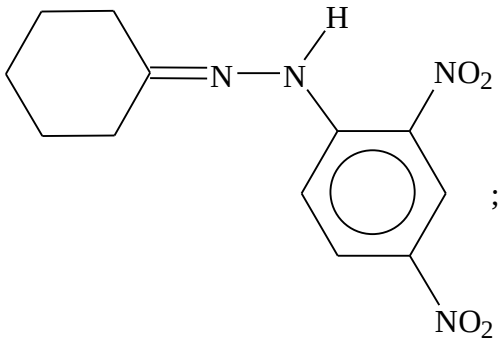
G3. (a) all C—C bonds in benzene or structure B are 0.139 (nm) (long) / the same length; structure A would have C—C bond lengths of 0.154 and 0.134 (nm) / benzene does not have C—C bond lengths of 0.154 or 0.134 (nm) / different bond lengths; ***[2]***
*If no reference to carbon-carbon bonds, award **[1]**.*

(b) (i) structure A would have value of (about) –360 (kJ mol^{-1});
150 (kJ mol^{-1}) / difference between –360 and –210 represents greater stability of benzene/structure B; ***[2]***

(ii) delocalized electrons; ***[1]***

G4. (a) addition-elimination / condensation; ***[1]***

(b)



; + H_2O ;

[2]

*Award **[1]** for correct structural formula of the organic product and **[1]** for water.*

(c) the (crystalline) solid has a characteristic melting point; ***[1]***