Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Thursday 14 May 2015 (afternoon)

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 maximum mark for this examination paper is **[40 marks]**.

2215 – 6113

The Periodic Table

1	2											3	4	5	6	7	0
1 **H** 1.01																	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)															

Atomic number

Element

Relative atomic mass

†	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. What is the total number of protons and electrons in one mole of hydrogen gas?

A. 2

B. 4

C. 1.2×10^{24}

D. 2.4×10^{24}

2. Which expression gives the sum of all the coefficients for the general equation for the complete combustion of hydrocarbons?

$$\_\_\_ C_xH_y(g) + \_\_\_ O_2(g) \rightarrow \_\_\_ CO_2(g) + \_\_\_ H_2O(l)$$

A. $1 + x + \frac{y}{4}$

B. $1 + x + \frac{y}{2}$

C. $1 + 2x + \frac{3y}{4}$

D. $1 + 2x + \frac{3y}{2}$

3. A gas with a molar mass (M) of $44\,g\,mol^{-1}$ occupies a volume of $2.00 \times 10^3\,cm^3$ at a pressure of $1.01 \times 10^5\,Pa$ and a temperature of 25 °C. Which expression is correct for the calculation of the mass of the gas, in g? ($R = 8.31\,J\,K^{-1}\,mol^{-1}$)

A. $\frac{44 \times 1.01 \times 10^5 \times 2.00 \times 10^{-3}}{8.31 \times 298}$

B. $\frac{44 \times 1.01 \times 10^5 \times 2.00 \times 10^{3}}{8.31 \times 25}$

C. $\frac{1.01 \times 10^5 \times 2.00 \times 10^{-3}}{44 \times 8.31 \times 298}$

D. $\frac{44 \times 1.01 \times 10^5 \times 2.00 \times 10^{3}}{8.31 \times 298}$

4. Which ion will be deflected most in a mass spectrometer?

A. $^{16}O^{+}$

B. $^{16}O^{2+}$

C. $^{18}O^{+}$

D. $^{18}O^{2+}$

5. What is the electron configuration of the copper(I) ion, Cu^+?

A. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^9$

B. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$

C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$

D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

6. Which combination of properties best describes sodium oxide, Na_2O?

	Nature of bonding	Acidic or basic behaviour
A.	covalent	acidic
B.	ionic	basic
C.	covalent	basic
D.	ionic	acidic

7. What is the definition of electronegativity?

A. The relative measure of the tendency of an atom when bonded in a molecule to attract a shared pair of electrons towards itself.

B. The minimum energy required to remove a mole of electrons from a mole of gaseous atoms.

C. The enthalpy change occurring in $kJ\,mol^{-1}$ when a gaseous atom gains one electron to form a negative ion.

D. The strength of an atom measured in $kJ\,mol^{-1}$ to attract an electron to itself when bonded in a molecule.

8. Which species cannot act as a ligand?

A. NH_4^+

B. H_2O

C. Cl^-

D. OH^-

9. The formula of gallium phosphate is $GaPO_4$. What is the correct formula of gallium sulfate?

A. $GaSO_4$

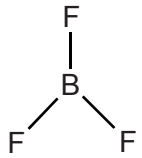
B. GaS

C. $Ga_2(SO_4)_3$

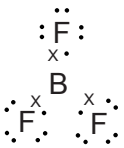
D. Ga_2S_3

10. Which diagrams can be used to represent the Lewis (electron dot) structure of boron trifluoride?

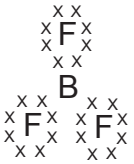
I.



II.



III.



A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which correctly lists butane ($M_r = 58$), propanone ($M_r = 58$), propan-1-ol ($M_r = 60$) and propan-2-ol ($M_r = 60$) in order of **increasing** boiling point?

A. $C_4H_{10} < CH_3COCH_3 < CH_3CH(OH)CH_3 < CH_3CH_2CH_2OH$

B. $CH_3CH_2CH_2OH < CH_3CH(OH)CH_3 < CH_3COCH_3 < C_4H_{10}$

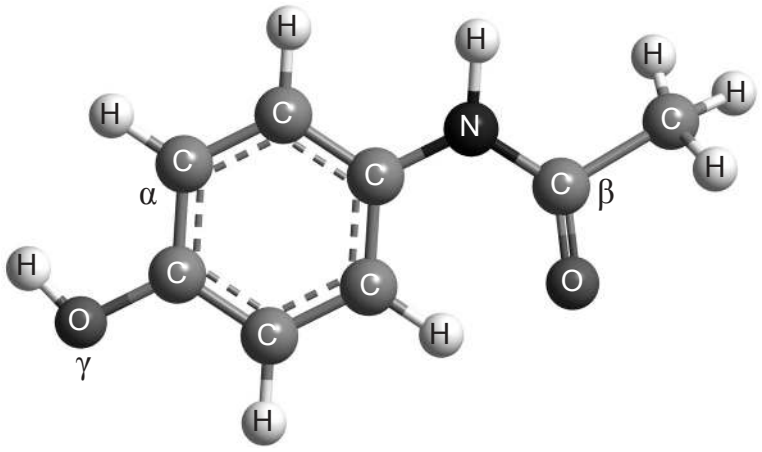
C. $C_4H_{10} < CH_3CH(OH)CH_3 < CH_3CH_2CH_2OH < CH_3COCH_3$

D. $C_4H_{10} < CH_3COCH_3 < CH_3CH_2CH_2OH < CH_3CH(OH)CH_3$

12. Which combination of shape and bond angle is correct for a molecule of xenon tetrafluoride, XeF_4?

	Shape	Bond angle
A.	square pyramid	90°
B.	square planar	90°
C.	tetrahedral	109.5°
D.	octahedral	90°

13. Which combination correctly describes the types of hybridization shown by the two carbon atoms labelled α and β and the oxygen atom labelled γ in the molecule of paracetamol shown below?



Paracetamol

	α	β	γ
A.	sp^2	sp^2	sp^3
B.	sp^3	sp^2	sp^2
C.	sp^2	sp^2	sp^2
D.	sp^2	sp^3	sp^3

14. When four moles of aluminium and four moles of iron combine with oxygen to form their oxides, the enthalpy changes are –3338 kJ and –1644 kJ respectively.

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s) \qquad \Delta H = -3338\,kJ$$
$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \qquad \Delta H = -1644\,kJ$$

What is the enthalpy change, in kJ, for the reduction of one mole of iron(III) oxide by aluminium?

$$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s)$$

A. +1694

B. +847

C. –847

D. –1694

15. Which enthalpy changes can be calculated using **only** bond enthalpy data?

I. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

II. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$

III. $CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Which equation represents the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of tetrachloromethane?

A. $C(g) + 4Cl(g) \rightarrow CCl_4(g)$

B. $C(s) + 4Cl(g) \rightarrow CCl_4(l)$

C. $C(g) + 2Cl_2(g) \rightarrow CCl_4(g)$

D. $C(s) + 2Cl_2(g) \rightarrow CCl_4(l)$

17. What is the correct order for **increasing** lattice enthalpy?

A. $MgO < MgCl_2 < NaCl < CsCl$

B. $CsCl < NaCl < MgCl_2 < MgO$

C. $NaCl < CsCl < MgO < MgCl_2$

D. $NaCl < CsCl < MgCl_2 < MgO$

18. Which combinations of values will result in a spontaneous reaction?

	ΔH / kJ mol^{-1}	ΔS / J K^{-1} mol^{-1}	T / K
I.	−100	−100	300
II.	+100	−100	300
III.	+100	+100	3000

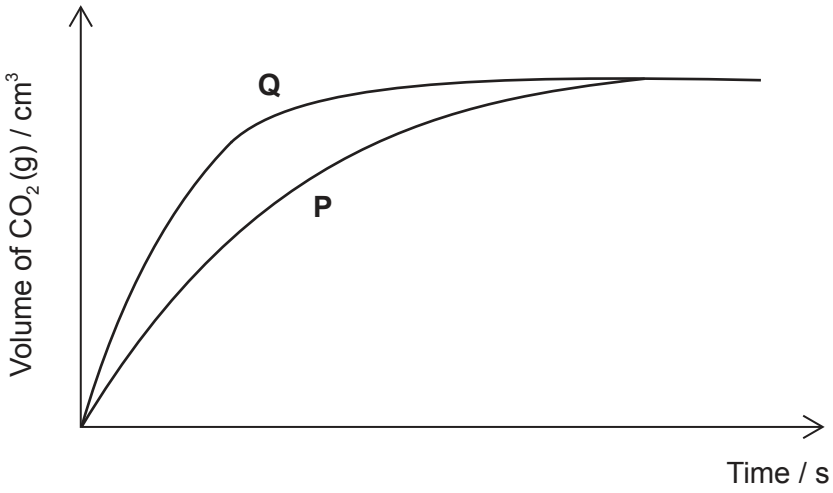
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

19. 100 cm^3 of a 1.00 mol dm^{-3} solution of hydrochloric acid is added to 2.00 g of small pieces of calcium carbonate at 20 °C. The volume of carbon dioxide produced against time is plotted to give curve **P**.



Which change will produce curve **Q**, given that calcium carbonate is always the limiting reagent?

A. Increasing the volume of the hydrochloric acid to 200 cm^3

B. Increasing the mass of calcium carbonate to 4.00 g

C. Increasing the concentration of the hydrochloric acid to 2.00 mol dm^{-3}

D. Replacing the 2.00 g of small pieces of calcium carbonate with 2.00 g of larger pieces of calcium carbonate

20. What are the units of the rate constant for a zero-order reaction?

A. s

B. s^{-1}

C. $mol^{-1}\ dm^3\ s^{-1}$

D. mol $dm^{-3}\ s^{-1}$

21. The hydrolysis of tertiary bromoalkanes with a warm dilute aqueous sodium hydroxide solution proceeds by a two-step S_N1 mechanism.

Step I: $R{-}Br \rightarrow R^+ + Br^-$

Step II: $R^+ + OH^- \rightarrow R{-}OH$

Which description of this reaction is consistent with the above information?

	Step I	Step II	Rate expression
A.	fast	slow	rate $= k[R{-}Br]$
B.	slow	fast	rate $= k[R{-}Br]$
C.	fast	slow	rate $= k[R{-}Br][OH^-]$
D.	slow	fast	rate $= k[R{-}Br][OH^-]$

22. Which combination of temperature and pressure will give the greatest yield of sulfur trioxide?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ$$

	Temperature	Pressure
A.	high	low
B.	low	high
C.	high	high
D.	low	low

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

$$2A(g) + 3B(g) \rightleftharpoons C(g) + 3D(g)$$

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

A. $\frac{1}{6}$

B. $\frac{9}{7}$

C. 3

D. 6

24. Which species **cannot** function as a Lewis acid?

A. BF_3

B. $AlCl_3$

C. CCl_4

D. H^+

25. 10.0 cm^3 of a 1.00×10^{-2} $mol\,dm^{-3}$ aqueous solution of sodium hydroxide is added to a volumetric flask and the total volume is made up to 1.00 dm^3 with distilled water. The resulting solution is then thoroughly mixed.

What is the pH of the diluted solution?

A. 9

B. 10

C. 12

D. 14

26. The strengths of four acids are:

glycine	$pK_a = 9.87$
chloroethanoic acid	$K_a = 1.38 \times 10^{-3}$
phenol	$K_a = 1.00 \times 10^{-10}$
butanoic acid	$pK_a = 4.82$

What is the order of **increasing** acid strength?

A. chloroethanoic acid < butanoic acid < phenol < glycine

B. glycine < phenol < chloroethanoic acid < butanoic acid

C. phenol < chloroethanoic acid < butanoic acid < glycine

D. phenol < glycine < butanoic acid < chloroethanoic acid

27. The pK_a of ethanoic acid is 4.8 at 298 K. Which combination will produce a buffer solution with a pH of 4.8 at 298 K?

A. $20.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ CH_3COOH and $10.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ NaOH

B. $20.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ CH_3COOH and $20.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ NaOH

C. $10.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ CH_3COOH and $20.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ NaOH

D. $14.8\,cm^3$ of $1.0\,mol\,dm^{-3}$ CH_3COOH and $10.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ NaOH

28. Which compound forms an acidic solution when dissolved in water?

A. $FeCl_3$

B. CH_3NH_2

C. $NaNO_3$

D. Na_2CO_3

29. For which titration can the end point **not** be determined accurately by using an acid-base indicator?

A. $NH_3(aq) + CH_3COOH(aq)$

B. $NaOH(aq) + HNO_3(aq)$

C. $NH_3(aq) + HNO_3(aq)$

D. $NaOH(aq) + CH_3COOH(aq)$

30. Which is a redox reaction?

A. $[Cu(H_2O)_4]^{2+}(aq) + 4Cl^-(aq) \rightarrow [CuCl_4]^{2-}(aq) + 4H_2O(l)$

B. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

C. $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

D. $2K_2CrO_4(aq) + 2HCl(aq) \rightarrow K_2Cr_2O_7(aq) + H_2O(l) + 2KCl(aq)$

31. What is the coefficient for I^- when the following equation is balanced using the smallest possible whole numbers?

$$IO_3^-(aq) + \_\_\_ I^-(aq) + \_\_\_ H^+(aq) \rightarrow \_\_\_ I_2(aq) + \_\_\_ H_2O(l)$$

A. 1

B. 2

C. 3

D. 5

32. The standard electrode potentials for three reactions involving copper and copper ions are:

$$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq) \qquad E^\ominus = +0.15\,V$$
$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) \qquad E^\ominus = +0.34\,V$$
$$Cu^+(aq) + e^- \rightleftharpoons Cu(s) \qquad E^\ominus = +0.52\,V$$

Which statement is correct?

A. Cu^{2+} ions are a better oxidizing agent than Cu^+ ions.

B. Copper metal is a better reducing agent than Cu^+ ions.

C. Cu^+ ions will spontaneously form copper metal and Cu^{2+} ions in solution.

D. Copper metal can be spontaneously oxidized by Cu^{2+} ions to form Cu^+ ions.

33. The same quantity of electricity is passed through separate dilute aqueous solutions of sulfuric acid and copper(II) sulfate using platinum electrodes under the same conditions. Which statement is correct?

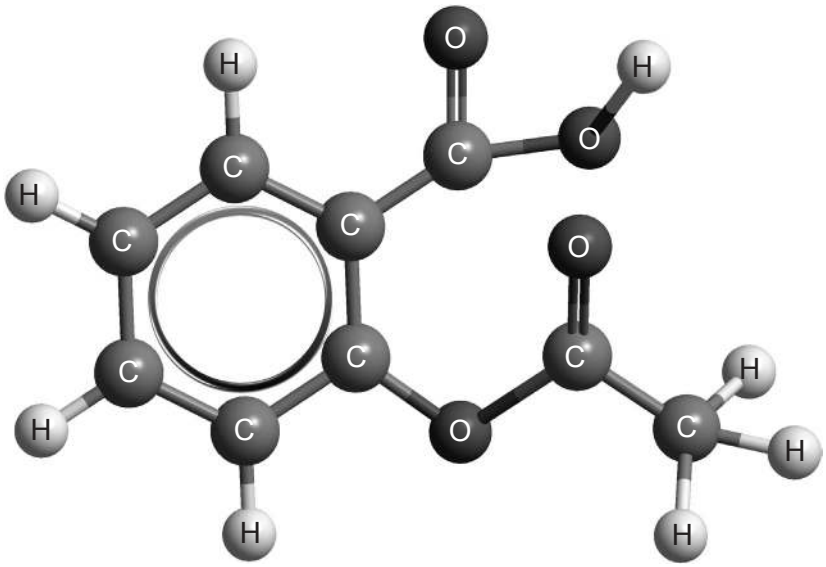
A. The same volume of oxygen is obtained in both cases.

B. The same volume of hydrogen is obtained in both cases.

C. The amount of copper deposited at the negative electrode in the copper(II) sulfate solution is half the amount of hydrogen gas formed at the negative electrode in the sulfuric acid solution.

D. The pH of both solutions increases as the electrolysis proceeds.

34. Which of the following functional groups are present in aspirin?



Aspirin

A. Hydroxyl (alcohol) and ester

B. Carboxyl (carboxylic acid) and ester

C. Carboxyl (carboxylic acid) and carbonyl (ketone)

D. Hydroxyl (alcohol) and carbonyl (ketone)

35. Which statements are correct for the reaction of ethene with bromine in the absence of ultraviolet light?

I. It is an addition reaction.

II. The organic product is colourless.

III. The organic product is saturated.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

36. Applying IUPAC rules, what is the name of $CH_3CH(CH_3)CONH_2$?

A. Aminobutanone

B. 1-amino-2-methylpropanone

C. 2-methylpropanamide

D. Butanamide

37. What is the correct order for the **increasing** rate of hydrolysis of halogenoalkanes by dilute aqueous sodium hydroxide?

A. $CH_3CH(CH_3)CH_2Cl < CH_3CHClCH_2CH_3 < (CH_3)_3CCl < (CH_3)_3CBr$

B. $(CH_3)_3CBr < (CH_3)_3CCl < CH_3CHClCH_2CH_3 < CH_3CH(CH_3)CH_2Cl$

C. $(CH_3)_3CCl < (CH_3)_3CBr < CH_3CHClCH_2CH_3 < CH_3CH(CH_3)CH_2Cl$

D. $CH_3CHClCH_2CH_3 < CH_3CH(CH_3)CH_2Cl < (CH_3)_3CBr < (CH_3)_3CCl$

38. Which pairs of compounds can react together to undergo condensation polymerization reactions?

I. $HOOC–C_6H_4–COOH$ and C_2H_5OH

II. $H_2N–(CH_2)_6–NH_2$ and $HOOC–(CH_2)_4–COOH$

III. $H_2N–CH_2–COOH$ and $H_2N–CH(CH_3)–COOH$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

39. How many four-membered ring isomers are there of dichlorocyclobutane, $C_4H_6Cl_2$?

A. 3

B. 4

C. 5

D. 6

40. What is the best way to minimize the random uncertainty when titrating an acid of unknown strength against a standard solution of sodium hydroxide (*ie* one of known concentration)?

A. First standardize the sodium hydroxide solution against a standard solution of a different acid.

B. Use a pH meter rather than an indicator to determine the equivalence point.

C. Keep your eye at the same height as the meniscus when reading the burette.

D. Repeat the titration several times.