Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Thursday 11 May 2017 (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]**.

2217 – 6107

16 pages

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01			Atomic number **Element** Relative atomic mass														2 **He** 4.00
2	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
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
6	55 **Cs** 132.91	56 **Ba** 137.33	57† **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Unt** (286)	114 **Uug** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. Which compound has the greatest percentage by mass of nitrogen atoms?

A. N_2H_4

B. NH_3

C. N_2O_4

D. $NaNO_3$

2. Which statements about mixtures are correct?

I. The components may be elements or compounds.
II. All components must be in the same phase.
III. The components retain their individual properties.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

3. What is the expression for the volume of hydrogen gas, in dm^3, produced at STP when 0.30 g of magnesium reacts with excess hydrochloric acid solution?

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Molar volume of an ideal gas at STP $= 22.7\,dm^3\,mol^{-1}$

A. $\frac{0.30 \times 2 \times 22.7}{24.31}$

B. $\frac{0.30 \times 22.7}{24.31}$

C. $\frac{0.30 \times 24.31}{22.7}$

D. $\frac{0.30 \times 22.7}{24.31 \times 2}$

4. Which electron transition in the hydrogen atom emission spectrum emits radiation with the longest wavelength?

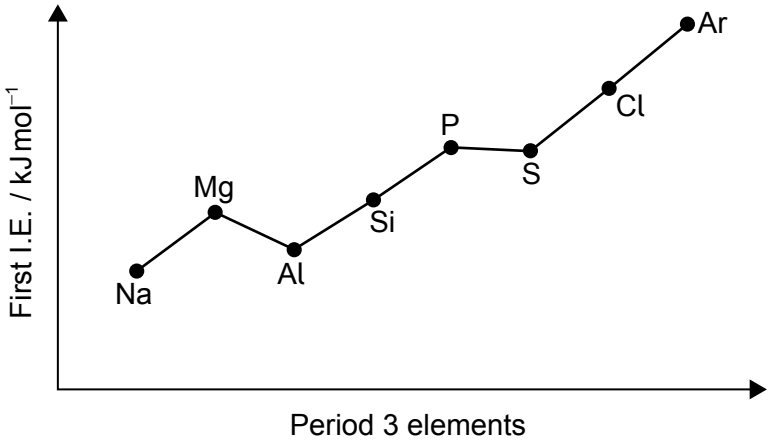
A. $n = 2 \rightarrow n = 1$

B. $n = 1 \rightarrow n = 2$

C. $n = 4 \rightarrow n = 1$

D. $n = 3 \rightarrow n = 2$

5. Which statement explains one of the decreases in first ionization energy (I.E.) across period 3?



A. The nuclear charge of element Al is greater than element Mg.

B. The electron-electron repulsion is greater, for the electron with the opposite spin, in element S than in element P.

C. A new sub-level is being filled at element S.

D. The p orbital being filled in element Al is at a lower energy than the s orbital in element Mg.

6. What is the order of decreasing ionic radius?

A. $S^{2-} > Cl^{-} > Al^{3+} > Mg^{2+}$

B. $Cl^{-} > S^{2-} > Al^{3+} > Mg^{2+}$

C. $S^{2-} > Cl^{-} > Mg^{2+} > Al^{3+}$

D. $Mg^{2+} > Al^{3+} > Cl^{-} > S^{2-}$

7. Which oxide, when added to water, produces the solution with the highest pH?

A. Na_2O

B. SO_3

C. MgO

D. CO_2

8. What is the charge on the iron(III) complex ion in $[Fe(OH)_2(H_2O)_4]Br$?

A. 0

B. 1+

C. 2+

D. 3+

9. A substance has the following properties:

Melting point / °C	Electrical conductivity	
	Molten	Solid
1414	poor	poor

What is the most probable structure of this substance?

A. Network covalent

B. Polar covalent molecule

C. Ionic lattice

D. Metallic lattice

10. Which two atoms form the most polar bond?

A. C and F

B. C and Cl

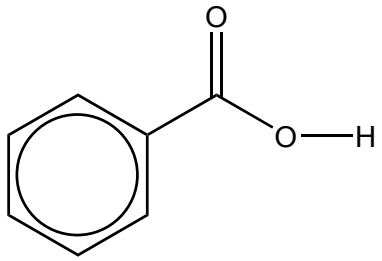
C. Si and F

D. Si and Cl

11. Which combination describes the PH_4^+ ion?

	Molecular geometry	Central atom hybridization
A.	Tetrahedral	sp^3
B.	Square planar	sp^3
C.	Tetrahedral	sp^2
D.	Square planar	sp^2

12. Which combination describes the bonding and structure in benzoic acid, C_6H_5COOH?



	Number of electron domains per carbon atom	Number of π-electrons	Number of σ-bonds
A.	3	6	6
B.	3	8	15
C.	4	6	6
D.	4	8	10

13. Which species have resonance structures?

I. Ozone, O_3
II. Carbon dioxide, CO_2
III. Benzene, C_6H_6

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

14. Which expression gives the mass, in g, of ethanol required to produce 683.5 kJ of heat upon complete combustion?

(M_r for ethanol = 46.0, $\Delta H_c^{\ominus} = -1367\,\text{kJ mol}^{-1}$)

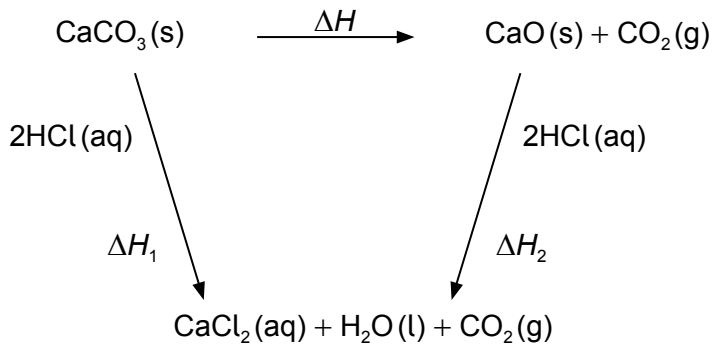
A. $\dfrac{683.5}{1367 \times 46.0}$

B. $\dfrac{1367}{683.5 \times 46.0}$

C. $\dfrac{683.5 \times 46.0}{1367}$

D. $\dfrac{1367 \times 46.0}{683.5}$

15. Which expression gives the enthalpy change, ΔH, for the thermal decomposition of calcium carbonate?



A. $\Delta H = \Delta H_1 - \Delta H_2$

B. $\Delta H = 2\Delta H_1 - \Delta H_2$

C. $\Delta H = \Delta H_1 - 2\Delta H_2$

D. $\Delta H = \Delta H_1 + \Delta H_2$

16. Which equation represents enthalpy of hydration?

A. $\text{Na}(g) \rightarrow \text{Na}^+(aq) + e^-$

B. $\text{Na}^+(g) \rightarrow \text{Na}^+(aq)$

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

D. $\text{NaCl}(s) \rightarrow \text{Na}^+(aq) + \text{Cl}^-(aq)$

17. Which combination of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ will result in a non-spontaneous reaction at all temperatures?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	positive	negative
B.	negative	positive
C.	positive	positive
D.	negative	negative

18. Copper catalyses the reaction between zinc and dilute sulfuric acid.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Why does copper affect the reaction?

A. Decreases the activation energy

B. Increases the activation energy

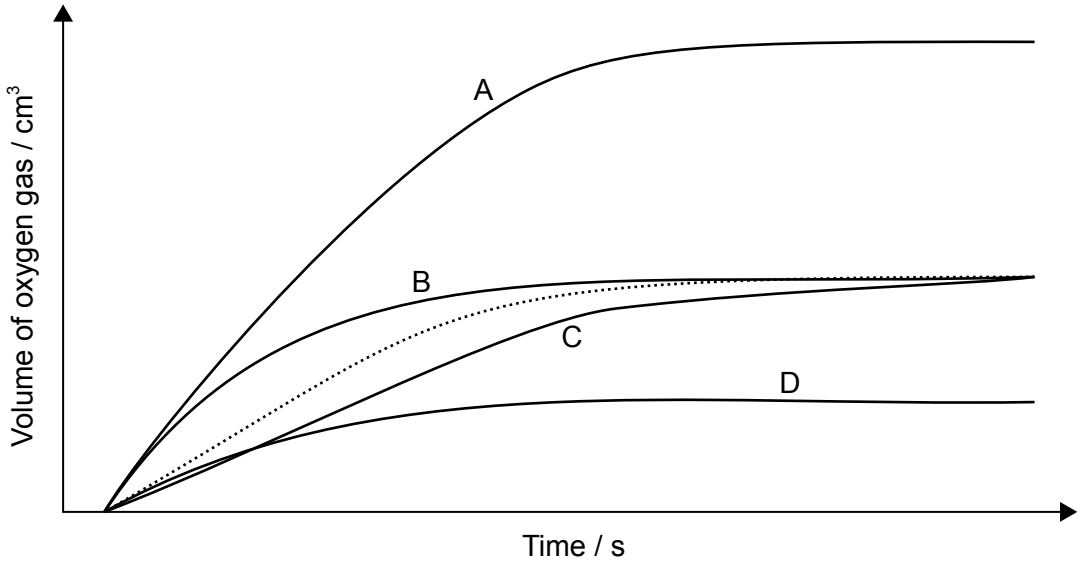
C. Increases the enthalpy change

D. Decreases the enthalpy change

19. 100 cm^3 of 10 % hydrogen peroxide solution decomposes at 298 K to form water and oxygen.

$$H_2O_2(aq) \rightarrow H_2O(l) + \frac{1}{2}O_2(g)$$

The dotted line graph represents the volume of oxygen produced.



Which graph represents the decomposition of an equal volume of a 20 % solution under the same conditions?

20. The table gives rate data for the reaction in a suitable solvent.

$$C_4H_9Br + OH^- \rightarrow C_4H_9OH + Br^-$$

Initial [C_4H_9Br] / mol dm^{-3}	**Initial [OH^-] / mol dm^{-3}**	**Initial rate of reaction / mol dm^{-3} s^{-1}**
0.02	0.02	2.0×10^{-3}
0.04	0.02	4.0×10^{-3}
0.02	0.04	2.0×10^{-3}
0.04	0.04	4.0×10^{-3}

Which statement is correct?

A. The rate expression is rate $= k$ [C_4H_9Br] [OH^-].

B. The rate increases by a factor of 4 when the [OH^-] is doubled.

C. C_4H_9Br is a primary halogenoalkane.

D. The reaction occurs via S_N1 mechanism.

21. What are the units for the rate constant, k, in the expression?

$$\text{Rate} = k\,[\text{X}]^2[\text{Y}]$$

A. $\text{mol}^2\,\text{dm}^{-6}\,\text{s}^{-1}$

B. $\text{mol}^{-1}\,\text{dm}^3\,\text{s}^{-1}$

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

D. $\text{mol}^{-2}\,\text{dm}^6\,\text{s}^{-1}$

22. Consider the equilibrium between $N_2O_4(g)$ and $NO_2(g)$.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +58\,\text{kJ}\,\text{mol}^{-1}$$

Which changes shift the position of equilibrium to the right?

I. Increasing the temperature
II. Decreasing the pressure
III. Adding a catalyst

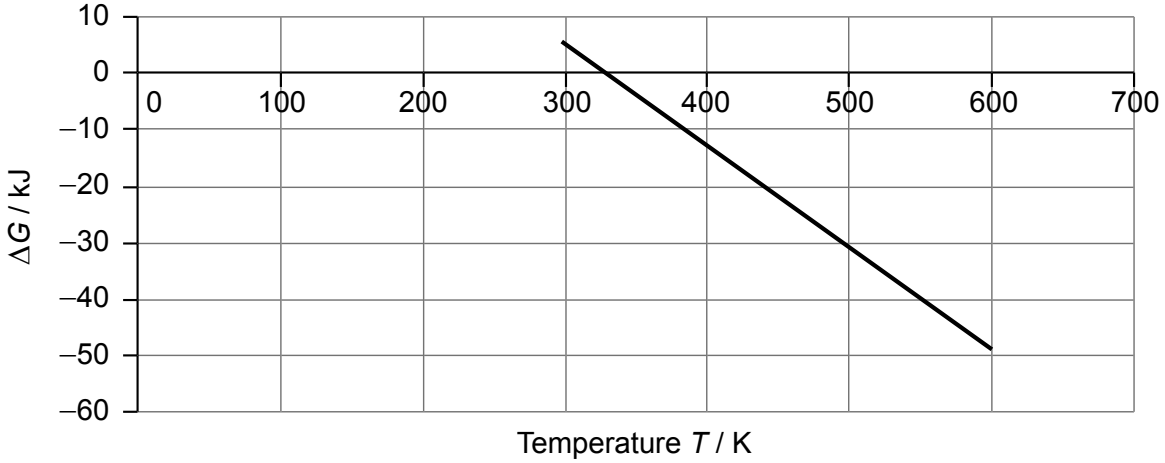
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

23. The graph shows values of ΔG for a reaction at different temperatures.



Which statement is correct?

A. The standard entropy change of the reaction is negative.

B. The standard enthalpy change of the reaction is positive.

C. At higher temperatures, the reaction becomes less spontaneous.

D. The standard enthalpy change of the reaction is negative.

24. Which species produced by the successive dissociations of phosphoric acid, H_3PO_4, are amphiprotic?

A. HPO_4^{2-} and PO_4^{3-}

B. $H_2PO_4^-$ and HPO_4^{2-}

C. $H_2PO_4^-$ and PO_4^{3-}

D. HPO_4^{2-} only

25. What is the pH of $1.0 \times 10^{-3}\,\text{mol}\,\text{dm}^{-3}$ sodium hydroxide, NaOH (aq)?

$$K_w = 1.0 \times 10^{-14}$$

A. 3

B. 4

C. 10

D. 11

26. Which species acts as a Lewis and Brønsted–Lowry base?

A. $[Al(H_2O)_6]^{3+}$

B. BF_3

C. NH_4^+

D. OH^-

27. A buffer is produced by mixing 20.0 cm^3 of 0.10 mol dm^{-3} ethanoic acid, $CH_3COOH(aq)$, with 0.10 mol dm^{-3} sodium hydroxide, NaOH (aq).

What is the volume of NaOH required and the pH of the buffer?

	Volume of NaOH / cm^3	pH of buffer
A.	40.0	9.2
B.	40.0	4.8
C.	10.0	9.2
D.	10.0	4.8

28. Which change represents oxidation?

A. $HClO_4$ to $HClO_3$

B. N_2 to NH_3

C. N_2O to NO

D. SO_4^{2-} to SO_3^{2-}

29. A reaction takes place when a rechargeable battery is used:

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

Which statements are correct?

I. H^+ is reduced
II. The oxidation state of Pb metal changes from 0 to +2
III. PbO_2 is the oxidising agent

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Which statement is correct for the overall reaction in a voltaic cell?

$$2AgNO_3(aq) + Ni(s) \rightarrow 2Ag(s) + Ni(NO_3)_2(aq) \qquad E^{\ominus} = +1.06\,V$$

A. Electrons flow from Ag electrode to Ni electrode.

B. Ni is oxidized to Ni^{2+} at the cathode (negative electrode).

C. Ag^+ is reduced to Ag at the anode (positive electrode).

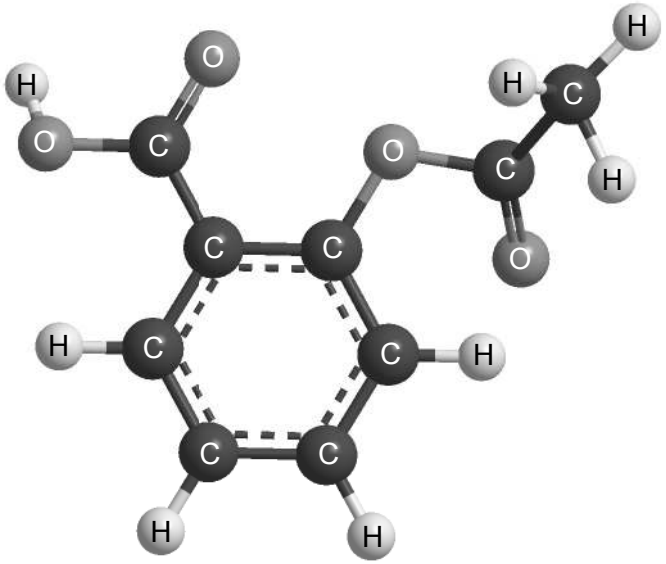
D. Ag has a more positive standard electrode potential value than Ni.

31. In the electrolysis of aqueous potassium nitrate, $KNO_3(aq)$, using inert electrodes, 0.1 mol of a gas was formed at the cathode (negative electrode).

Which is correct?

	Gaseous product at anode (positive electrode)	**Amount of product at anode / mol**
A.	hydrogen	0.05
B.	oxygen	0.05
C.	hydrogen	0.2
D.	oxygen	0.2

32. What are the functional groups in the aspirin molecule?



I. Ether
II. Carboxyl
III. Ester

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

33. Which molecule has a tertiary nitrogen?

A. $(CH_3)_2NH$

B. $(C_2H_5)_4N^+I^-$

C. $C_3H_7N(CH_3)_2$

D. $C_6H_5NH_2$

34. What can be determined about a molecule from the number of signals in its ^1H NMR spectrum?

A. Bonds present

B. Molecular formula

C. Molecular mass

D. Number of hydrogen environments

35. What is the major product of the reaction between 2-methylbut-2-ene and hydrogen bromide?

A. 3-bromo-2-methylbutane

B. 3-bromo-3-methylbutane

C. 2-bromo-3-methylbutane

D. 2-bromo-2-methylbutane

36. What is the product of the reduction of 2-methylbutanal?

A. 2-methylbutan-1-ol

B. 2-methylbutan-2-ol

C. 3-methylbutan-2-one

D. 2-methylbutanoic acid

37. Which molecule is chiral?

A. 2-chlorobutane

B. 2,2-dichloropentane

C. Propan-2-amine

D. 4-hydroxybutanoic acid

38. The molar mass of a gas, determined experimentally, is $32\,g\,mol^{-1}$. Its literature molar mass is $40\,g\,mol^{-1}$.

What is the percentage error?

A. 80 %

B. 25 %

C. 20 %

D. 8 %

39. What is the density, in $g\,cm^{-3}$, of a 34.79 g sample with a volume of 12.5 cm^3?

A. 0.359

B. 0.36

C. 2.783

D. 2.78

40. Which technique is used to determine the bond lengths and bond angles of a molecule?

A. X-ray crystallography

B. Infrared (IR) spectroscopy

C. Mass spectroscopy

D. ^1H NMR spectroscopy