Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
## Paper 1

Wednesday 7 November 2018 (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]**.

15 pages

International Baccalaureate
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The Periodic Table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
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
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
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)
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 **Uuq** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

Atomic number

Element

Relative atomic mass

† | 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. How many moles of FeS_2 are required to produce 32 g of SO_2? (A_r: S = 32, O = 16)

$$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$$
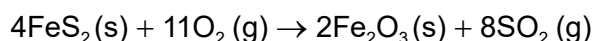
A.   0.25

B.   0.50

C.   1.0

D.   2.0

2. The volume of a sample of gas measured at 27 °C is 10.0 dm³. What is the temperature when the volume is reduced to 9.0 dm³ at the same pressure?

A.   −3.0 °C

B.   24.3 °C

C.   29.7 °C

D.   57.0 °C

3. An antacid tablet containing 0.50 g of $NaHCO_3$ ($M_r = 84$) is dissolved in water to give a volume of 250 cm³. What is the concentration, in mol dm⁻³, of HCO_3^- in this solution?

A. $\dfrac{0.250 \times 84}{0.50}$

B. $\dfrac{0.50}{84 \times 0.250}$

C. $\dfrac{250 \times 84}{0.50}$

D. $\dfrac{0.50}{84 \times 250}$

4. Which statements are correct for the emission spectrum of hydrogen?

    I.   The lines converge at higher frequencies.

    II.   Electron transitions to n = 2 are responsible for lines in the visible region.

    III. Lines are produced when electrons move from lower to higher energy levels.

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

Turn over

5. The values for the first three successive ionization energies for two elements **X** and **Z** are given.

Element	First ionization energy / kJ mol^{-1}	Second ionization energy / kJ mol^{-1}	Third ionization energy / kJ mol^{-1}
X	520	7300	11 800
Z	1090	2350	4610

Which pair of elements represents **X** and **Z**?

	X	**Z**
A.	Li	Be
B.	Li	C
C.	Be	Li
D.	Be	C

6. Which oxides produce an acidic solution when added to water?

   I. Al_2O_3 and SiO_2
   II. P_4O_6 and P_4O_{10}
   III. NO_2 and SO_2

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

7. Which species will require the least energy for the removal of one electron?

A. Na^+

B. Mg^+

C. Al^{2+}

D. C^{3+}

8. Which is correct for the complex ion in $[Fe(H_2O)_5Cl]SO_4$?

	Oxidation state of iron	Overall charge of the complex ion
A.	+2	2+
B.	+2	0
C.	+3	1+
D.	+3	2+

9. Which species has the same molecular geometry as SO_3^{2-}?

A. BF_3

B. SO_3

C. PF_3

D. CO_3^{2-}

10. How many lone pairs and bonding pairs of electrons surround the central chlorine atom in ClF_2^+?

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

11. Which compound has the highest boiling point?

A. CH_3CHO

B. CH_3CH_2F

C. CH_3OCH_3

D. $CH_3CH_2NH_2$

Turn over

12. What is the number of sigma (σ) and pi (π) bonds in the molecule $(NC)_2C=C(CN)_2$?

	σ	π
A.	9	9
B.	5	9
C.	13	5
D.	9	5

13. What is the hybridization of the circled carbon, oxygen and nitrogen atoms?
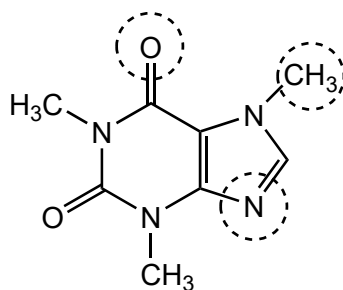
	Carbon	Oxygen	Nitrogen
A.	sp^3	sp	sp
B.	sp^2	sp^2	sp
C.	sp^2	sp^3	sp^2
D.	sp^3	sp^2	sp^2

14. Consider the following reactions:

$$Fe_2O_3(s) + CO(g) \rightarrow 2FeO(s) + CO_2(g) \qquad \Delta H^{\ominus} = -3\,kJ$$
$$Fe(s) + CO_2(g) \rightarrow FeO(s) + CO(g) \qquad \Delta H^{\ominus} = +11\,kJ$$
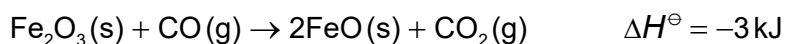
What is the $\Delta H^{\ominus}$ value, in kJ, for the following reaction?

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$
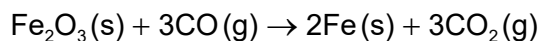
A.   −25

B.   −14

C.   +8

D.   +19

15. Which is correct when $Ba(OH)_2$ reacts with NH_4Cl?

$$Ba(OH)_2(s) + 2NH_4Cl(s) \rightarrow BaCl_2(aq) + 2NH_3(g) + 2H_2O(l) \qquad \Delta H^{\ominus} = +164\,kJ\,mol^{-1}$$
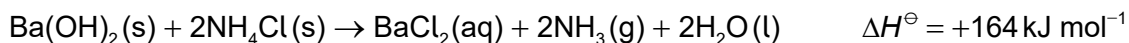
	Temperature	Enthalpy	Stability
A.	increases	products have lower enthalpy than the reactants	products are less stable than the reactants
B.	decreases	products have lower enthalpy than the reactants	products are more stable than the reactants
C.	decreases	products have higher enthalpy than the reactants	products are less stable than the reactants
D.	increases	products have higher enthalpy than the reactants	products are more stable than the reactants

Turn over

16. What are the signs of $\Delta H^\ominus$ and $\Delta S^\ominus$ for the reaction, which is spontaneous at low temperature and non-spontaneous at very high temperature?

$$\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$$

$$SO_3(g) + CaO(s) \rightarrow CaSO_4(s)$$
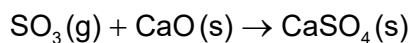
	$\Delta H^\ominus$	$\Delta S^\ominus$
A.	+	−
B.	−	+
C.	−	−
D.	+	+

17. Which change is exothermic?

A. $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$

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

C. $KCl(s) \rightarrow K^+(g) + Cl^-(g)$

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

18. Samples of sodium carbonate powder were reacted with separate samples of excess hydrochloric acid.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + 2NaCl(aq) + H_2O(l)$$

Reaction I: 1.0 g $Na_2CO_3(s)$ added to 0.50 mol dm^{-3} HCl(aq)
Reaction II: 1.0 g $Na_2CO_3(s)$ added to 2.0 mol dm^{-3} HCl(aq)

What is the same for reactions I and II?

A.   Initial rate of reaction

B.   Total mass of CO_2 produced

C.   Total reaction time

D.   Average rate of production of CO_2

19. What decreases the activation energy of a reaction?

    A.   Increasing the temperature

    B.   Adding a catalyst

    C.   Adding more reactants

    D.   Increasing collision frequency of reactants

20. Compounds **X** and **Y** were mixed and the time taken for a colour to appear was recorded at various reactant concentrations.
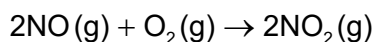
Experiment	[X] / mol dm^{-3}	[Y] / mol dm^{-3}	Time / s
1	0.12	0.16	20
2	0.06	0.16	40
3	0.12	0.08	80

What are the orders of reaction with respect to **X** and **Y**?

	X	Y
A.	1	2
B.	$\frac{1}{2}$	$\frac{1}{4}$
C.	2	1
D.	2	4

21. The rate expression for the reaction is: rate $= k\,[NO]^2[O_2]$.

$$2NO\,(g) + O_2\,(g) \rightarrow 2NO_2\,(g)$$

Which mechanism is **not** consistent with this rate expression?

A.	$NO + NO \rightleftharpoons N_2O_2$ $N_2O_2 + O_2 \rightarrow 2NO_2$	*fast* *slow*
B.	$2NO + O_2 \rightarrow 2NO_2$	*slow*
C.	$NO + O_2 \rightarrow NO_2 + O$ $NO + O \rightarrow NO_2$	*slow* *fast*
D.	$NO + O_2 \rightleftharpoons NO_3$ $NO_3 + NO \rightarrow 2NO_2$	*fast* *slow*

22. Consider the reaction:

$$2N_2O\,(g) \rightleftharpoons 2N_2\,(g) + O_2\,(g)$$

The values of K_c at different temperatures are:

| Temperature / K	K_c
838	1.10×10^{-3}
1001	3.80×10^{-1}
1030	8.71×10^{-1}
1053	1.67

Which statement is correct at higher temperature?

A.   The forward reaction is favoured.

B.   The reverse reaction is favoured.

C.   The rate of the reverse reaction is greater than the rate of the forward reaction.

D.   The concentration of both reactants and products increase.

23. Which combination describes the system at equilibrium?

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

24. Which two species act as Brønsted–Lowry acids in the reaction?

$$H_2PO_4^-(aq) + OH^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H_2O(l)$$
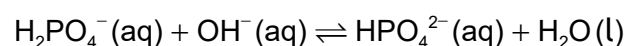
A. $HPO_4^{2-}(aq)$ and $OH^-(aq)$

B. $H_2PO_4^-(aq)$ and $HPO_4^{2-}(aq)$

C. $HPO_4^{2-}(aq)$ and $H_2O(l)$

D. $H_2PO_4^-(aq)$ and $H_2O(l)$

25. What is the order of increasing pH for the following solutions of the same concentration?

A. $NaCl < NH_4Cl < Na_2CO_3 < CH_3COONa$
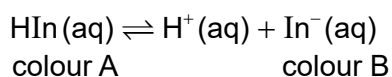
B. $CH_3COONa < NH_4Cl < NaCl < Na_2CO_3$

C. $NH_4Cl < NaCl < CH_3COONa < Na_2CO_3$

D. $Na_2CO_3 < CH_3COONa < NaCl < NH_4Cl$

26. Which species is **not** a Lewis base?

A. OH^-

B. NH_4^+

C. H_2O

D. PH_3

27. An indicator, HIn, has a pK_a of 5.1.

$$HIn\,(aq) \rightleftharpoons H^+\,(aq) + In^-\,(aq)$$
$$\text{colour A} \qquad\qquad \text{colour B}$$

Which statement is correct?

A.   At pH $= 7$, colour B would be observed

B.   At pH $= 3$, colour B would be observed

C.   At pH $= 7$, $[HIn] = [In^-]$

D.   At pH $= 3$, $[HIn] < [In^-]$

28. Which is correct for the reaction?

$$P_4\,(s) + 3H_2O\,(l) + 3OH^-\,(aq) \rightarrow PH_3\,(g) + 3H_2PO_2^-\,(aq)$$
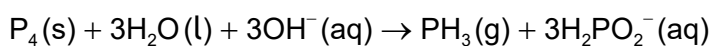
	Oxidizing agent	Reducing agent
A.	H_2O	P_4
B.	P_4	OH^-
C.	OH^-	P_4
D.	P_4	P_4

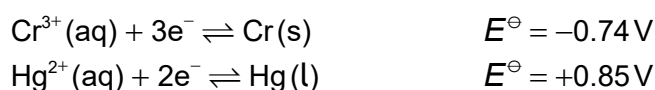**29.** Which describes the flow of electrons in a voltaic cell?

A.   From the cathode (positive electrode) to the anode (negative electrode) through the external circuit

B.   From the anode (negative electrode) to the cathode (positive electrode) through the external circuit

C.   From the oxidizing agent to the reducing agent through the salt bridge

D.   From the reducing agent to the oxidizing agent through the salt bridge

30. Which is correct for a redox reaction where the standard electrode potential is negative?
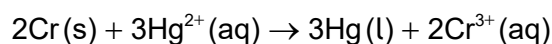
$$\Delta G^{\ominus} = -nFE^{\ominus} \text{ and } \Delta G^{\ominus} = -RT \ln K$$

A. $\Delta G^{\ominus}$ is negative and K is less than 1.

B. $\Delta G^{\ominus}$ is negative and K is greater than 1.

C. $\Delta G^{\ominus}$ is positive and K is less than 1.

D. $\Delta G^{\ominus}$ is positive and K is greater than 1.

31. Consider the standard electrode potentials:

$$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s) \qquad\qquad E^{\ominus} = -0.74\,V$$
$$Hg^{2+}(aq) + 2e^- \rightleftharpoons Hg(l) \qquad\qquad E^{\ominus} = +0.85\,V$$

What is the cell potential, in V, for the voltaic cell?

$$2Cr(s) + 3Hg^{2+}(aq) \rightarrow 3Hg(l) + 2Cr^{3+}(aq)$$

A.   −1.59

B.   +0.11

C.   +1.07

D.   +1.59

32. Which compounds cause the colour of acidified potassium manganate(VII) solution to change from purple to colourless?

　　　I. $CH_3CH_2CH_2CH_2OH$

　　　II. $(CH_3)_3CCH_2OH$

　　　III. $CH_3CH_2CH(OH)CH_3$

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

Turn over

33. Which is correct for benzene?

    A.   It readily undergoes addition reactions and decolourises bromine water.

    B.   It contains alternate single and double carbon–carbon bonds and is planar.

    C.   Its ^1H NMR spectrum shows six signals and it readily undergoes substitution reactions.

    D.   Its ^1H NMR spectrum shows one signal and it forms a single C_6H_5Br isomer.

34. Which compounds react to form $CH_3CH_2CH_2COOCH(CH_3)_2$?

    A.   propanoic acid and propan-2-ol

    B.   propanoic acid and butan-2-ol

    C.   butanoic acid and propan-1-ol

    D.   butanoic acid and propan-2-ol

35. Which statement about the reaction of a hydroxide ion with the organic reagent is correct?

    A.   1-bromopentane predominantly follows an S_N1 mechanism.

    B.   2-bromo-2-methylbutane predominantly follows an S_N2 mechanism.

    C.   Reaction with 1-bromopentane occurs at a slower rate than with 1-chloropentane.

    D.   Reaction with 1-bromopentane occurs at a slower rate than with 2-bromo-2-methylbutane.

36. What is the major product of the reaction of HBr with but-1-ene?

    A.   1-bromobutane

    B.   2-bromobutane

    C.   1,2-dibromobutane

    D.   2,2-dibromobutane

37. How many chiral carbon atoms are present in one molecule of $(CH_3)_2CHCHClCHBrCH_3$?

    A.   0

    B.   1

    C.   2

    D.   3

38. What is the ratio of areas under each signal in the ^{1}H NMR spectrum of 2-methylbutane?

    A. $6:1:2:3$

    B. $3:3:1:5$

    C. $6:1:5$

    D. $3:3:1:2:3$

39. What are the absolute and percentage uncertainties for the change in mass?

Initial mass: $22.35 \pm 0.05\,g$
Final mass: $42.35 \pm 0.05\,g$

	Absolute uncertainty / g	Percentage uncertainty
A.	±0.05	0.1%
B.	±0.10	0.5%
C.	±0.05	0.5%
D.	±0.10	0.1%

40. Which technique may be used to find the bond lengths and bond angles within a molecule?

    A.   X-ray crystallography

    B. ^{1}H NMR spectroscopy

    C.   Infrared spectroscopy

    D.   Mass spectroscopy