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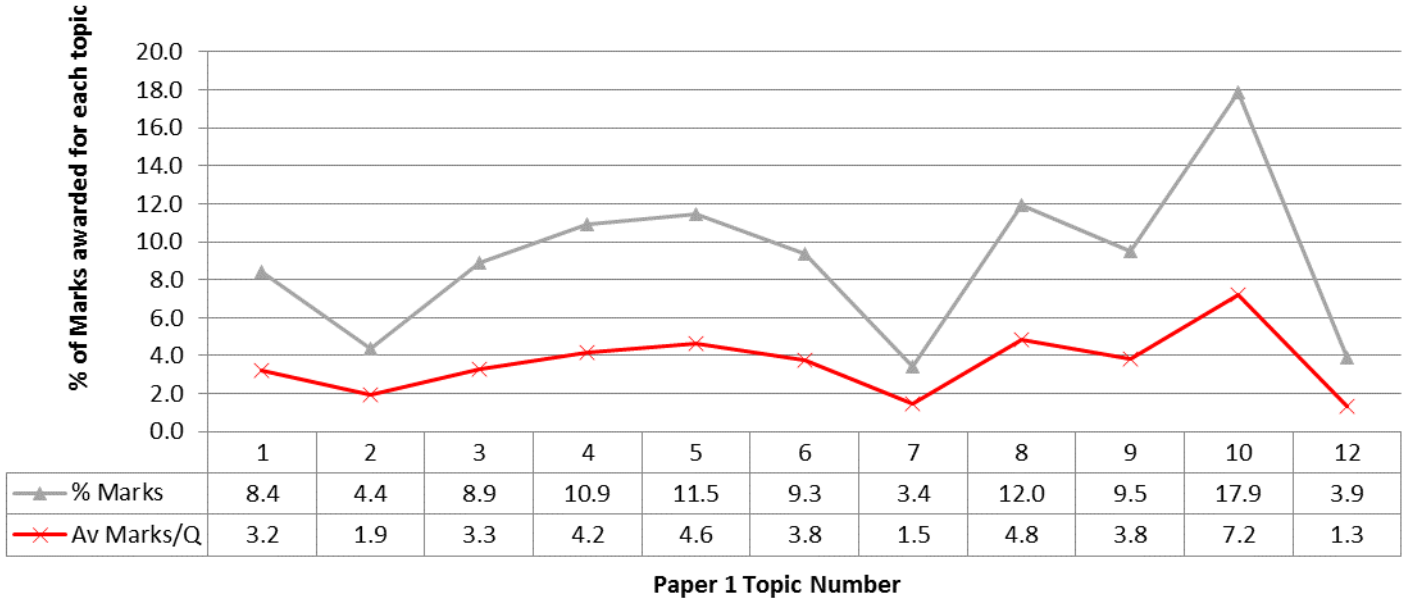
PAPER 1

Percentage of all marks awarded for each topic from s2008 to w2014 (TZ 0, 1 & 2) and average marks per question per topic (red)



	1	2	3	4	5	6	7	8	9	10	12
% Marks	8.4	4.4	8.9	10.9	11.5	9.3	3.4	12.0	9.5	17.9	3.9
Av Marks/Q	3.2	1.9	3.3	4.2	4.6	3.8	1.5	4.8	3.8	7.2	1.3

	1	2	3	4	5	6	7	8	9	10	x	Total
Total Marks	71	37	75	92	97	79	29	101	80	151	33	845
% of Marks	8.4	4.4	8.9	10.9	11.5	9.3	3.4	12.0	9.5	17.9	3.9	100
# of Questions	22	19	23	22	21	21	20	21	21	21	25	236
Average marks per Q	**3.2**	**1.9**	**3.3**	**4.2**	**4.6**	**3.8**	**1.5**	**4.8**	**3.8**	**7.2**	**1.3**	40

Topic x refers to questions from discontinued sections of the syllabus: in T2 how a mass spectrometer works, T3 the chlorides of period 3 and in T7 (most of the marks) liquid-vapour equilibria

	1st Paper	**Last Paper**	# Papers	**Marks/ Paper**	Total Marks	**Actual All Marks**	Difference
Paper 1	s08	w14	21	40	840	845	5

1. 0.040 mol of $(NH_4)_2Ni(SO_4)_2 \cdot 6H_2O$ is dissolved in water to give 200 cm^3 of aqueous solution. What is the concentration, in mol dm^{-3}, of ammonium ions?

   A. 0.00040

   B. 0.0080

   C. 0.20

   D. 0.40

2. When sodium bromate(V), $NaBrO_3$, is heated, it reacts according to the equation below.

$$2NaBrO_3(s) \rightarrow 2NaBr(s) + 3O_2(g)$$

   What amount, in mol, of $NaBrO_3$ produces 2.4 dm^3 of oxygen gas, measured at room temperature and pressure? (Molar volume of gas = 24 $dm^3 mol^{-1}$ at room temperature and pressure.)

   A. 0.017

   B. 0.067

   C. 0.10

   D. 0.15

3. At which temperature, in K, assuming constant pressure, is the volume of a fixed mass of gas at 127 °C doubled?

   A. 200 K

   B. 254 K

   C. 400 K

   D. 800 K

1. What is the mass, in g, of one mole of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, given the following relative atomic mass values?

Element	Cu	S	H	O
Relative atomic mass	64	32	1	16

A. 160

B. 178

C. 186

D. 250

2. An excess of calcium carbonate is added to a solution containing 0.10 mol of HCl(aq). What mass of calcium carbonate reacts, and what mass of carbon dioxide is formed?

$$\text{Mass of one mole of } CaCO_3 = 100\,\text{g}$$

$$\text{Mass of one mole of } CO_2 = 44\,\text{g}$$

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

	$CaCO_3(s)$ / g	$CO_2(g)$ / g
A.	10	4.4
B.	10	2.2
C.	5.0	2.2
D.	5.0	4.4

3. For which compounds is the empirical formula the same as the molecular formula?

I. Methane

II. Ethene

III. Ethanol

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 1/Q# 3//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

D. $C_{12}H_8O_2$

2. Under which conditions does CH_4 have the same number of molecules as $100\,cm^3$ of O_2 at $27\,°C$ and 1.0×10^5 Pa?

	Volume / cm^3	Temperature / °C	Pressure / 10^5 Pa
A.	50	54	1.0
B.	50	327	1.0
C.	100	54	2.0
D.	100	327	2.0

3. $100.0\,cm^3$ of a $0.50\,mol\,dm^{-3}$ solution of $BaCl_2$ is added to $50.0\,cm^3$ of a $0.10\,mol\,dm^{-3}$ solution of Na_2SO_4. A precipitate of $BaSO_4$ is formed according to the equation below.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$$

What is the amount, in mol, of $BaSO_4$ produced?

A. 0.0050

B. 0.010

C. 0.050

D. 0.10

D. $C_{12}H_8O_2$

2. Under which conditions does CH_4 have the same number of molecules as $100\,cm^3$ of O_2 at $27\,°C$ and 1.0×10^5 Pa?

	Volume / cm^3	Temperature / °C	Pressure / 10^5 Pa
A.	50	54	1.0
B.	50	327	1.0
C.	100	54	2.0
D.	100	327	2.0

3. $100.0\,cm^3$ of a $0.50\,mol\,dm^{-3}$ solution of $BaCl_2$ is added to $50.0\,cm^3$ of a $0.10\,mol\,dm^{-3}$ solution of Na_2SO_4. A precipitate of $BaSO_4$ is formed according to the equation below.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$$

What is the amount, in mol, of $BaSO_4$ produced?

A. 0.0050

B. 0.010

C. 0.050

D. 0.10

Chem 1/Q# 4//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

1. What is the total number of oxygen atoms in 0.200 mol of glucose, $C_6H_{12}O_6$?

A. 1.20

B. 6.00

C. 1.20×10^{23}

D. 7.22×10^{23}

2. What are the coefficients of $H_2SO_4(aq)$ and $H_3PO_4(aq)$ when the following equation is balanced using the smallest possible whole numbers?

$$___ Ca_3(PO_4)_2(s) + ___ H_2SO_4(aq) \rightarrow ___ CaSO_4(s) + ___ H_3PO_4(aq)$$

	Coefficient of $H_2SO_4(aq)$	Coefficient of $H_3PO_4(aq)$
A.	1	2
B.	2	3
C.	3	1
D.	3	2

3. 7.102 g of Na_2SO_4 ($M = 142.04\,g\,mol^{-1}$) is dissolved in water to prepare $0.5000\,dm^3$ of solution. What is the concentration of Na_2SO_4 in $mol\,dm^{-3}$?

A. 2.500×10^{-2}

B. 1.000×10^{-1}

C. 1.000×10

D. 1.000×10^{2}

Chem 1/Q# 5//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

1. How many atoms are present in 0.10 mol of $PtCl_2(NH_3)_2$?

A. 6.0×10^{22}

B. 3.0×10^{23}

C. 6.6×10^{23}

D. 6.6×10^{24}

2. What mass of carbon dioxide, $CO_2(g)$, in g, is produced when 5.0 g of calcium carbonate, $CaCO_3(s)$, reacts completely with hydrochloric acid, $HCl(aq)$?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A. 0.050

B. 2.2

C. 4.4

D. 5.0

3. The volume occupied by one mole of an ideal gas at 273 K and 1.01×10^5 Pa is 22.4 $dm^3 mol^{-1}$. What volume of hydrogen, in dm^3, is produced when excess magnesium ribbon reacts with 100 cm^3 of 2.00 mol dm^{-3} hydrochloric acid?

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

A. 0.100

B. 2.24

C. 4.48

D. 22.4

Chem 1/Q# 6//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

1. What is the whole number ratio of the coefficients of ammonia to oxygen when the following equation is balanced correctly?

$$___ NH_3(g) + ___ O_2(g) \rightarrow ___ NO(g) + ___ H_2O(l)$$

A. 1 : 2

B. 2 : 1

C. 4 : 5

D. 5 : 4

2. When 50 cm^3 of a hydrocarbon, C_xH_y, was burned in excess oxygen, 200 cm^3 of carbon dioxide and 250 cm^3 of steam were produced (all volumes were measured under the same conditions). What is the molecular formula of the hydrocarbon?

A. C_2H_4

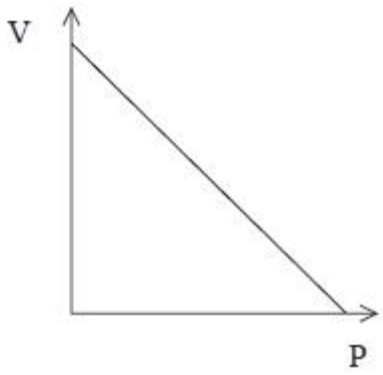
B. C_3H_8

C. C_4H_8

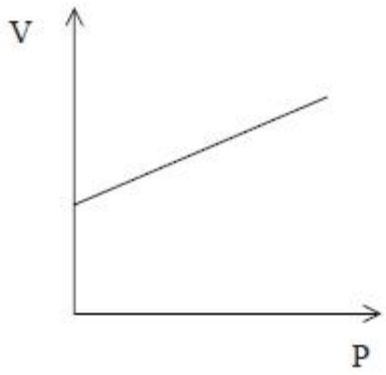
D. C_4H_{10}

3. Which graph represents the relationship between volume and pressure for a fixed mass of gas at constant temperature?

A.



B.



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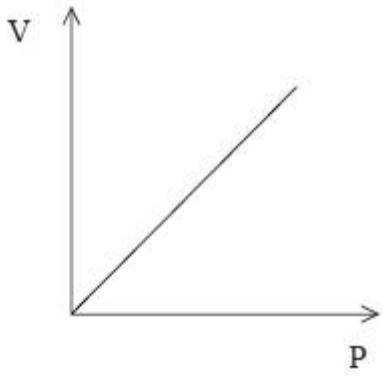
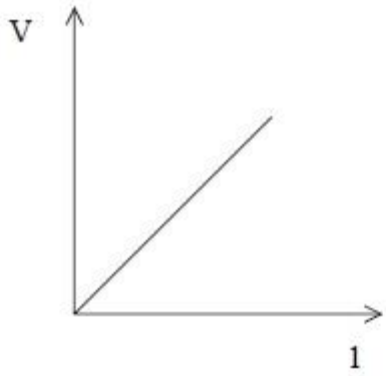


D.



Chem 1/Q# 7//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

1. What is the number of ions in 0.20 mol of $(NH_4)_3PO_4$?

A. 8.0×10^{-1}

B. 1.2×10^{23}

C. 4.8×10^{23}

D. 2.4×10^{24}

2. The equation for the reduction of iron(III) oxide is:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

What mass of carbon dioxide, in g, is produced by the complete reduction of 80 g of iron(III) oxide?

A. 44

B. 66

C. 88

D. 132

3. 3.0 dm^3 of ethyne, C_2H_2, is mixed with 3.0 dm^3 of hydrogen and ignited. The equation for the reaction that occurs is shown below.

$$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$$

Assuming the reaction goes to completion and all gas volumes are measured at the same temperature and pressure, what volume of ethane, C_2H_6, in dm^3, is formed?

A. 1.5

B. 2.0

C. 3.0

D. 6.0

Chem 1/Q# 8//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

1. What is the total number of atoms in 0.100 mol of $[Pt(NH_3)_2Cl_2]$?

A. 11

B. 6.02×10^{22}

C. 3.01×10^{23}

D. 6.62×10^{23}

2. Nitroglycerine, $C_3H_5N_3O_9$, can be used in the manufacture of explosives. What is the coefficient of $C_3H_5N_3O_9(l)$ when the equation for its decomposition reaction is balanced using the lowest whole numbers?

$$___ C_3H_5N_3O_9(l) \rightarrow ___ CO_2(g) + ___ H_2O(l) + ___ N_2(g) + ___ O_2(g)$$

A. 2

B. 4

C. 20

D. 33

3. The volume occupied by one mole of an ideal gas at 273 K and 1.01×10^5 Pa is 22.4 dm^3. What volume, in dm^3, is occupied by 3.20 g $O_2(g)$ at 273 K and 1.01×10^5 Pa?

A. 2.24

B. 4.48

C. 22.4

D. 71.7

4. What volume, in m^3, is occupied by 2.00 mol of gas at 27 °C and 2.00 atm pressure?
Assume: 1.00 atm = 1.01×10^5 Pa and $R = 8.31\ J\ K^{-1}\ mol^{-1}$.

A. $\frac{8.31\times27}{1.01\times10^5}$

B. $\frac{2.00\times8.31\times27}{1.01\times10^5}$

C. $\frac{2.00\times8.31\times300}{2.00\times1.01\times10^5}$

D. $\frac{2.00\times8.31\times300}{1.01\times10^5}$

1. How many atoms of hydrogen are in 0.500 mol of CH_3OH molecules?

   A. 1.20×10^{23}

   B. 3.01×10^{23}

   C. 6.02×10^{23}

   D. 1.20×10^{24}

2. Calcium carbonate reacts with hydrochloric acid according to the following equation.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

   What is the theoretical yield, in mol, of calcium chloride if 0.10 mol $CaCO_3$ is added to 100 cm^3 of 1.0 mol dm^{-3} HCl?

   A. 0.050

   B. 0.10

   C. 0.20

   D. 0.50

3. A fixed mass of an ideal gas at 27.0 °C and 1.01×10^5 Pa has a volume of 100 cm^3. Which change doubles the volume of the gas?

   A. Heating the gas at constant pressure to 54.0 °C.

   B. Heating the gas at constant pressure to 327 °C.

   C. Increasing the pressure on the gas to 2.02×10^5 Pa at constant temperature.

   D. Heating the gas to 54.0 °C and increasing the pressure to 2.02×10^5 Pa.

1. How many oxygen **atoms** are in 0.100 mol of $CuSO_4 \cdot 5H_2O$?

   A. 5.42×10^{22}

   B. 6.02×10^{22}

   C. 2.41×10^{23}

   D. 5.42×10^{23}

2. What is the sum of the coefficients when the following equation is balanced using whole numbers?

$$___ Fe_2O_3(s) + ___ CO(g) \rightarrow ___ Fe(s) + ___ CO_2(g)$$

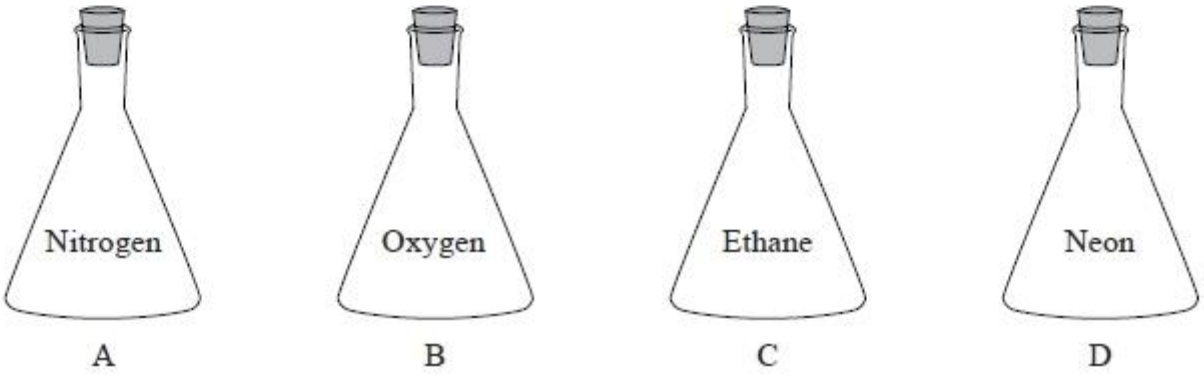
   A. 5

   B. 6

   C. 8

   D. 9

3. Four identical containers under the same conditions are filled with gases as shown below. Which container and contents will have the highest mass?



4. 1.0 dm^3 of an ideal gas at 100 kPa and 25 °C is heated to 50 °C at constant pressure. What is the new volume in dm^3?

A. 0.50

B. 0.90

C. 1.1

D. 2.0

5. What is the amount, in moles, of sulfate ions in 100 cm^3 of 0.020 mol dm^{-3} $FeSO_4(aq)$?

A. 2.0×10^{-3}

B. 2.0×10^{-2}

C. 2.0×10^{-1}

D. 2.0

Chem 1/Q# 11//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

1. What is the total number of hydrogen atoms in 1.0 mol of benzamide, $C_6H_5CONH_2$?

A. 7

B. 6.0×10^{23}

C. 3.0×10^{24}

D. 4.2×10^{24}

2. Chloroethene, C_2H_3Cl, reacts with oxygen according to the equation below.

$$2C_2H_3Cl(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g) + 2HCl(g)$$

What is the amount, in mol, of H_2O produced when 10.0 mol of C_2H_3Cl and 10.0 mol of O_2 are mixed together, and the above reaction goes to completion?

A. 4.00

B. 8.00

C. 10.0

D. 20.0

3. What is the concentration of NaCl, in mol dm^{-3}, when 10.0 cm^3 of 0.200 mol dm^{-3} NaCl solution is added to 30.0 cm^3 of 0.600 mol dm^{-3} NaCl solution?

A. 0.450

B. 0.300

C. 0.500

D. 0.800

Chem 1/Q# 12//**IB/Paper 1/2011/s/Time Zone 1/Higher Level/**

1. 1.7 g of $NaNO_3$ ($M_r = 85$) is dissolved in water to prepare 0.20 dm^3 of solution. What is the concentration of the resulting solution in mol dm^{-3}?

A. 0.01

B. 0.1

C. 0.2

D. 1.0

2. What mass, in g, of hydrogen is formed when 3 mol of aluminium react with excess hydrochloric acid according to the following equation?

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

A. 3.0

B. 4.5

C. 6.0

D. 9.0

3. The relative molecular mass of a gas is 56 and its empirical formula is CH_2. What is the molecular formula of the gas?

A. CH_2

B. C_2H_4

C. C_3H_6

D. C_4H_8

4. What is the sum of all coefficients when the following equation is balanced using the smallest possible whole numbers?

$$__C_2H_2 + __O_2 \rightarrow __CO_2 + __H_2O$$

A. 5

B. 7

C. 11

D. 13

Chem 1/Q# 13//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

1. On analysis, a compound with molar mass 60 g mol^{-1} was found to contain 12 g of carbon, 2 g of hydrogen and 16 g of oxygen. What is the molecular formula of the compound?

A. CH_2O

B. CH_4O

C. C_2H_4O

D. $C_2H_4O_2$

2. 300 cm^3 of water is added to a solution of 200 cm^3 of 0.5 mol dm^{-3} sodium chloride. What is the concentration of sodium chloride in the new solution?

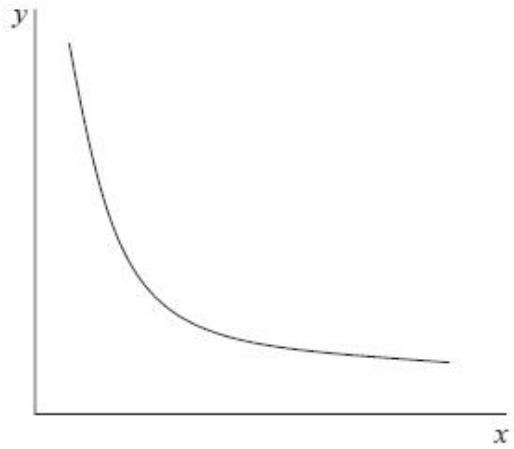
A. 0.05 mol dm^{-3}

B. 0.1 mol dm^{-3}

C. 0.2 mol dm^{-3}

D. 0.3 mol dm^{-3}

3. The graph below represents the relationship between two variables in a fixed amount of gas.



Which variables could be represented by each axis?

	x-axis	*y*-axis
A.	pressure	temperature
B.	volume	temperature
C.	pressure	volume
D.	temperature	volume

Chem 1/Q# 14//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

1. What is the mass, in g, of one molecule of ethane, C_2H_6?

A. 3.0×10^{-23}

B. 5.0×10^{-23}

C. 30

D. 1.8×10^{25}

2. 6.0 mol of aluminium reacts with oxygen to form aluminium oxide. What is the amount of oxygen, in mol, needed for complete reaction?

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

A. 1.5

B. 3.0

C. 4.5

D. 6.0

3. Which of the following is consistent with Avogadro's law?

A. $\frac{P}{T}$ = constant (V, n constant)

B. $\frac{V}{T}$ = constant (P, n constant)

C. Vn = constant (P, T constant)

D. $\frac{V}{n}$ = constant (P, T constant)

4. A sample of element X contains 69 % of ^{63}X and 31 % of ^{65}X. What is the relative atomic mass of X in this sample?

A. 63.0

B. 63.6

C. 65.0

D. 69.0

Chem 1/Q# 15//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

1. What is the approximate molar mass, in g mol^{-1}, of $MgSO_4 \cdot 7H_2O$?

A. 120

B. 130

C. 138

D. 246

2. Which is both an empirical and a molecular formula?

A. C_5H_{12}

B. C_5H_{10}

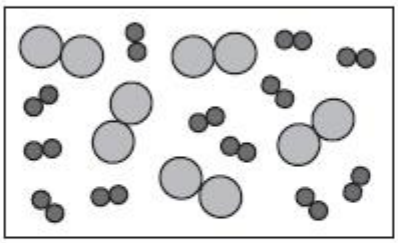
C. C_4H_8

D. C_4H_{10}

3. 12 molecules of hydrogen gas, $H_2(g)$, and 5 molecules of oxygen gas, $O_2(g)$, were mixed together under conditions which allowed the reaction to go to completion, according to the following equation.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

The following diagram represents the mixture of reactants.



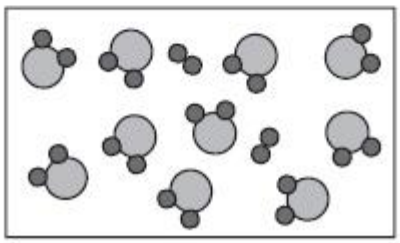
Key:

Oxygen atom

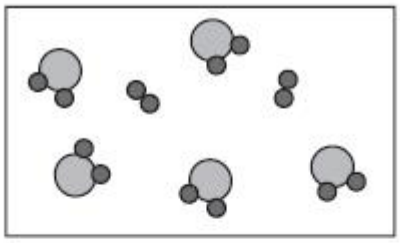
Hydrogen atom

Which diagram represents the reaction mixture when the reaction was complete?

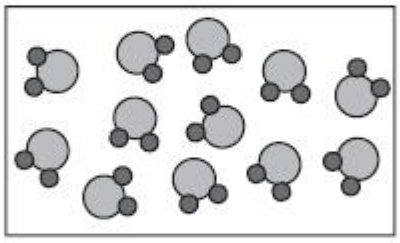
A.



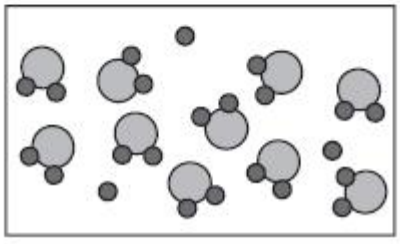
B.



C.



D.



1. Which coefficients would balance this equation?

$$__ MnO_2 + __ HCl \rightarrow __ MnCl_2 + __ Cl_2 + __ H_2O$$

	MnO_2	HCl	$MnCl_2$	Cl_2	H_2O
A.	1	2	1	1	1
B.	1	3	1	1	1
C.	1	4	1	1	2
D.	1	4	1	2	2

2. What volume of carbon dioxide, in dm^3 under standard conditions, is formed when 7.00 g of ethene (C_2H_4, $M_r = 28.1$) undergoes complete combustion?

A. $\frac{22.4 \times 28.1}{7.00}$

B. $\frac{22.4 \times 7.00}{28.1}$

C. $\frac{2 \times 22.4 \times 28.1}{7.00}$

D. $\frac{2 \times 22.4 \times 7.00}{28.1}$

3. What will be the concentration of sulfate ions in $mol\,dm^{-3}$ when 0.20 mol of $KAl(SO_4)_2$ is dissolved in water to give 100 cm^3 of aqueous solution?

A. 0.2

B. 1.0

C. 2.0

D. 4.0

4. The volume of an ideal gas at 27.0 °C is increased from 3.00 dm^3 to 6.00 dm^3. At what temperature, in °C, will the gas have the original pressure?

A. 13.5

B. 54.0

C. 327

D. 600

Chem 1/Q# 17//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

1. What is the number of oxygen atoms in one mole of $CuSO_4 \cdot 5H_2O$?

A. 5

B. 9

C. 6.0×10^{23}

D. 5.4×10^{24}

2. Which sample has the greatest mass?

A. 6.0×10^{25} molecules of hydrogen

B. 5.0 mol of neon atoms

C. 1.2×10^{24} atoms of silver

D. 1.7×10^{2} g of iron

3. What volume of sulfur trioxide, in cm^3, can be prepared using 40 cm^3 sulfur dioxide and 20 cm^3 oxygen gas by the following reaction? Assume all volumes are measured at the same temperature and pressure.

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

A. 20

B. 40

C. 60

D. 80

2. Which sample has the greatest mass?

A. 6.0×10^{25} molecules of hydrogen

B. 5.0 mol of neon atoms

C. 1.2×10^{24} atoms of silver

D. 1.7×10^{2} g of iron

3. What volume of sulfur trioxide, in cm^3, can be prepared using 40 cm^3 sulfur dioxide and 20 cm^3 oxygen gas by the following reaction? Assume all volumes are measured at the same temperature and pressure.

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

A. 20

B. 40

C. 60

D. 80

4. Which sample of nitrogen gas, N_2, contains the greatest number of nitrogen molecules?

A. 1.4 g N_2

B. 1.4 dm^3 of N_2 at 1.01×10^5 Pa and 273 K

C. 1.4×10^{23} N_2 molecules

D. 1.4 mol N_2

1. Which compound has the empirical formula with the largest mass?

   A. C_2H_6

   B. C_2H_4

   C. C_2H_2

   D. C_3H_6

2. 5 dm^3 of carbon monoxide, CO (g), and 2 dm^3 of oxygen, O_2(g), at the same temperature and pressure are mixed together. Assuming complete reaction according to the equation given, what is the maximum volume of carbon dioxide, CO_2(g), in dm^3, that can be formed?

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

   A. 3

   B. 4

   C. 5

   D. 7

3. Which statement about solutions is correct?

   A. When vitamin D dissolves in fat, vitamin D is the solvent and fat is the solute.

   B. In a solution of NaCl in water, NaCl is the solute and water is the solvent.

   C. An aqueous solution consists of water dissolved in a solute.

   D. The concentration of a solution is the amount of solvent dissolved in 1 dm^3 of solution.

1. Analytical chemists can detect amounts of amino acids as small as 2.0×10^{-21} mol of molecules. How many molecules does this represent?

A. 2.0×10^{-21}

B. 1.2×10^{3}

C. 6.0×10^{23}

D. 3.0×10^{44}

2. What amount of solute ions, in moles, is present in 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution?

A. 2.5×10^{-3}

B. 5.0×10^{-3}

C. 1.0×10^{-2}

D. 5.0×10^{-2}

3. A blast furnace contains 1600 kg of iron(III) oxide (M_r=160) and 144 kg of carbon (A_r=12). Assuming that they react according to the following equation:

$$Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$$

what is the limiting reagent and the maximum theoretical yield of iron?

	Limiting reagent	Maximum theoretical yield of iron / kg
A.	iron(III) oxide	560
B.	iron(III) oxide	1120
C.	carbon	224
D.	carbon	448

Chem 1/Q# 20//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

1. What is the amount of **atoms**, in moles, in 88 g of carbon dioxide?

   A. 6.02×10^{23}

   B. 1.204×10^{24}

   C. 6

   D. 1

2. The isotopic abundances for an element, X, are $^{28}_{14}X = 20\%$ and $^{29}_{14}X = 80\%$. What is the relative atomic mass of element X?

   A. 14

   B. 28.2

   C. 28.5

   D. 28.8

3. What is the volume (in cm^3) of a 0.800 mol dm^{-3} solution of KOH needed for neutralization in a titration with 30.0 cm^3 of 0.200 mol dm^{-3} H_2SO_4?

   A. 7.50

   B. 60.0

   C. 15.0

   D. 30.0

Chem 1/Q# 21//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

15. The temperature of 1 dm^3 of a gas is increased from 32°C to 64°C at constant pressure. What is the new volume in dm^3?

   A. 1.1

   B. 1.3

   C. 1.6

   D. 2.0

1. How many molecules are present in a 9.0 g sample of water?

   A. 0.5

   B. 1.0

   C. 6.0×10^{23}

   D. 3.0×10^{23}

2. What is the coefficient for oxygen when this equation is balanced using the lowest whole number?

$$C_4H_{10} + O_2 \rightarrow CO + H_2O$$

   A. 4

   B. 5

   C. 9

   D. 13

3. What is the maximum mass of iron that can be produced from the reduction of 80 tonnes of iron(III) oxide ($M_r = 160$), based on this equation?

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

   A. 28 tonnes

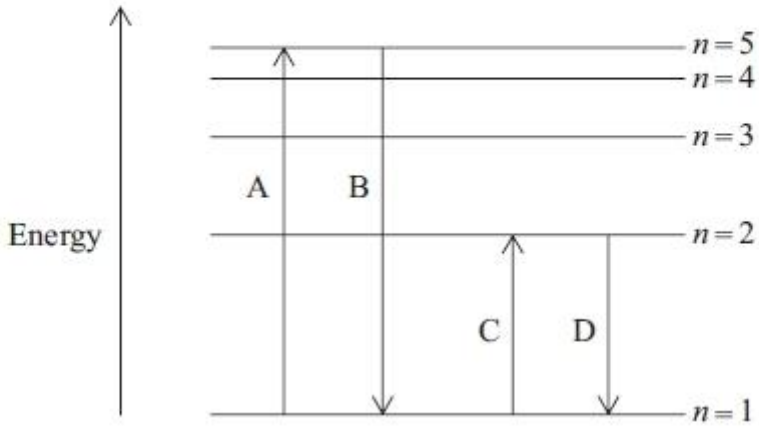
   B. 56 tonnes

   C. 84 tonnes

   D. 112 tonnes

Chem 2/Q# 23//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

4. Some possible electron transitions in a hydrogen atom are shown below. Which letter represents the electron transition with the highest energy in the emission spectrum of a hydrogen atom?



Chem 2/Q# 24//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

4. What is the abbreviated electron configuration of the cobalt(II) ion, Co^{2+}?

A. [Ar] $3d^7$

B. [Ar] $4s^2\ 3d^5$

C. [Ar] $4s^2\ 3d^7$

D. [Ar] $4s^1\ 3d^6$

5. Which statement correctly describes the atomic emission spectrum of hydrogen?

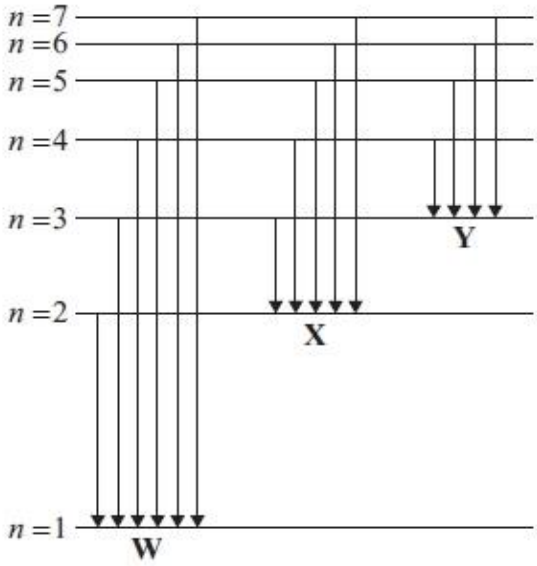
A. It is a continuous spectrum converging at high frequency.

B. It is a line spectrum converging at high frequency.

C. It is a continuous spectrum converging at low frequency.

D. It is a line spectrum converging at low frequency.

4. The diagram represents the emission spectrum of hydrogen. Groups of arrows are labelled **W**, **X** and **Y**.



Which statement is correct?

A. The arrows represent the transition of electrons to different energy levels when heat is supplied.

B. The arrows of **W** represent emission in the UV region.

C. The smallest arrow of **X** represents a violet line in the emission spectrum.

D. The arrows of **Y** represent emission of electromagnetic waves with higher energy than those represented by **X** and **W**.

5. Which electron configurations do **not** follow the Hund's rule?

	1s	2s	2p		
I.	↑ ↓	↑ ↓	↑	↑	↑
II.	↑ ↓	↑ ↓	↑ ↓	↑	
III.	↑ ↓	↑ ↓	↑	↓	↑

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 2/Q# 26//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

4. What are the numbers of neutrons and electrons in the iodine ion, $^{125}I^{+}$?

	Neutrons	Electrons
A.	53	53
B.	72	52
C.	72	53
D.	125	52

5. What is the abbreviated electron configuration of the telluride ion, Te^{2-}?

A. $[Kr]5s^2 5d^{10} 5p^6$

B. $[Kr]5s^2 4d^{10} 5p^2$

C. $[Kr]5s^2 4d^{10} 5p^4$

D. $[Kr]5s^2 4d^{10} 5p^6$

Chem 2/Q# 27//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

5. Which species has the electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$?

A. Ni

B. Ni^{2+}

C. Fe

D. Cu^{2+}

6. Element X is in group 5 and period 4 of the periodic table. Which statement is correct?

A. X has 5 occupied energy levels.

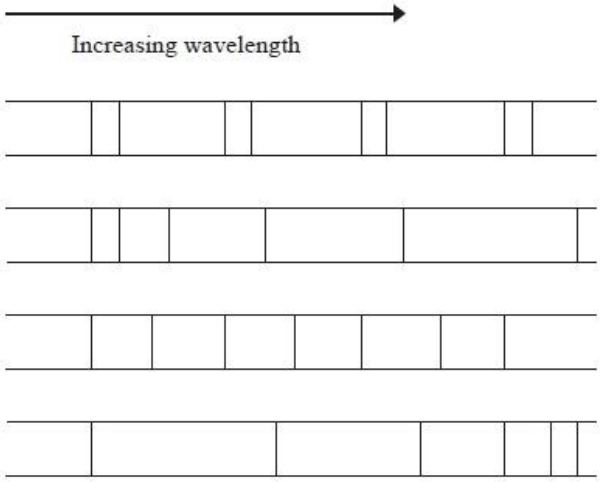
B. X can form ions with 3– charge.

C. X is a transition element.

D. X has 4 valence electrons.

Chem 2/Q# 28//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

4. Which diagram shows a pattern similar to the emission spectrum of hydrogen?



5. What is the correct electron configuration of the Cu^{+} ion?

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

B. [Ar] $3d^7\ 4s^2$

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

D. [Ar] $3d^8\ 4s^1$

Chem 2/Q# 29//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

5. In the electromagnetic spectrum, which will have the shortest wavelength **and** the greatest energy?

	Shortest wavelength	Greatest energy
A.	ultraviolet	ultraviolet
B.	infrared	infrared
C.	ultraviolet	infrared
D.	infrared	ultraviolet

6. What is the electron configuration of Sn^{2+}?

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^2$

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 4d^{10}\ 5p^2$

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^8\ 5p^2$

Chem 2/Q# 30//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

4. Which isotope has an atomic number of 9 and a mass number of 19?

A. ^{9}F

B. ^{19}K

C. ^{19}F

D. ^{28}Si

5. What is the order in which the energy sub-levels are occupied according to the Aufbau principle?

A. 5s, 5p, 4d

B. 4d, 5s, 5p

C. 5s, 4d, 5p

D. 5s, 5d, 5p

8. What are the electron configurations of Cu, Cu^{+} and Cu^{2+}?

	Cu	Cu^{+}	Cu^{2+}
A.	[Ar] $4s^2$ $3d^9$	[Ar] $4s^2$ $3d^8$	[Ar] $4s^2$ $3d^7$
B.	[Ar] $4s^2$ $3d^9$	[Ar] $4s^1$ $3d^9$	[Ar] $3d^9$
C.	[Ar] $4s^2$ $3d^9$	[Ar] $3d^{10}$	[Ar] $3d^9$
D.	[Ar] $4s^1$ $3d^{10}$	[Ar] $3d^{10}$	[Ar] $3d^9$

Chem 2/Q# 31//**IB/Paper 1/2011/w/Time Zone 0/Higher Level/**

6. Which shows the sub-levels in order of **increasing** energy in the fourth energy level of an atom?

A. f < d < p < s

B. p < d < f < s

C. d < f < p < s

D. s < p < d < f

4. Consider the relative abundance of the isotopes of element X.

Isotope	Relative abundance (%)
^{24}X	80
^{25}X	10
^{26}X	10

What is the relative atomic mass of X?

A. 24

B. 25

C. Between 24 and 25

D. Between 25 and 26

5. In the emission spectrum of hydrogen, which electronic transition would produce a line in the visible region of the electromagnetic spectrum?

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

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

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

D. $n = \infty \rightarrow n = 1$

Chem 2/Q# 33//**IB/Paper 1/2011/s/Time Zone 1/Higher Level/**

5. What is the electron configuration of vanadium?

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

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

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

D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

6. Which quantities are the same for all atoms of chlorine?

I. Number of protons

II. Number of neutrons

III. Number of electrons

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 2/Q# 34//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

4. Which statement about the species $^{63}Cu^{2+}$ and $^{65}Cu^{+}$ is correct?

A. Both species have the same number of protons.

B. Both species have the same number of electrons.

C. Both species have the same number of neutrons.

D. Both species have the same electron arrangement.

Chem 2/Q# 35//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

5. What is the electron configuration of Fe^{3+}?

A. $[Ar]4s^2 3d^6$

B. $[Ar]3d^5$

C. $[Ar]4s^2 3d^5$

D. $[Ar]4s^2 3d^3$

Chem 2/Q# 36//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

4. Which describes the visible emission spectrum of hydrogen?

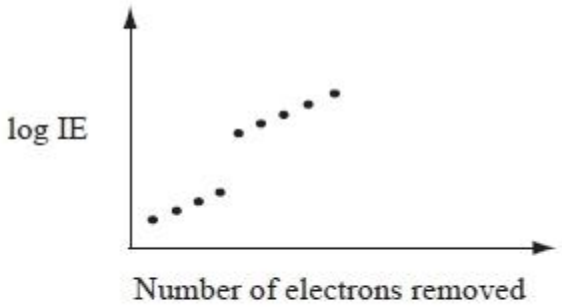
A. A series of lines converging at longer wavelength

B. A series of regularly spaced lines

C. A series of lines converging at lower energy

D. A series of lines converging at higher frequency

5. The graph represents the energy needed to remove nine electrons, one at a time, from an atom of an element. Not all of the electrons have been removed.



Which element could this be?

A. C

B. Si

C. P

D. S

6. An ion has the electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$. Which ion could it be?

A. Ni^{2+}

B. Cu^{+}

C. Cu^{2+}

D. Co^{3+}

5. The table below shows the number of protons, neutrons and electrons present in five species.

Species	Number of protons	Number of neutrons	Number of electrons
X	6	8	6
Y	7	7	7
Z	7	7	8
W	8	8	8
Q	8	10	8

Which two species are isotopes of the same element?

A. X and W

B. Y and Z

C. Z and W

D. W and Q

6. What is the order of increasing energy of the orbitals within a single energy level?

A. d < s < f < p

B. s < p < d < f

C. p < s < f < d

D. f < d < p < s

7. What is the electron configuration of the Cr^{2+} ion?

A. [Ar] $3d^5\ 4s^1$

B. [Ar] $3d^3\ 4s^1$

C. [Ar] $3d^6\ 4s^1$

D. [Ar] $3d^4\ 4s^0$

Chem 2/Q# 38//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

4. Which is correct for the following regions of the electromagnetic spectrum?

	UV		IR	
A.	high energy	short wavelength	low energy	low frequency
B.	high energy	low frequency	low energy	long wavelength
C.	high frequency	short wavelength	high energy	long wavelength
D.	high frequency	long wavelength	low frequency	low energy

5. Which species possesses only two unpaired electrons?

A. Zn

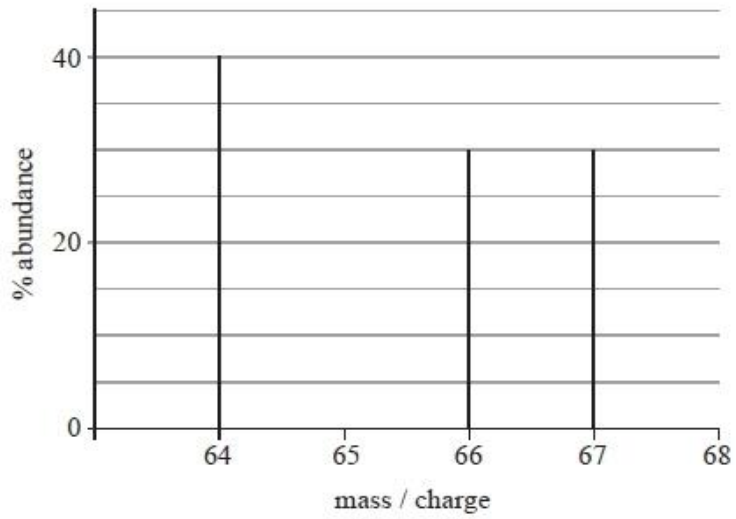
B. Mg

C. Ti^{2+}

D. Fe^{2+}

Chem 2/Q# 39//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

6. The mass spectrum of a sample of an element is shown below.



Which value is closest to the relative atomic mass of the element?

A. 64.5

B. 65.0

C. 65.5

D. 66.0

Chem 2/Q# 40//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

4. Which of the following describes the visible emission spectrum of hydrogen?

A. A set of lines which are randomly spaced.

B. A set of lines which converge towards a low energy value.

C. A set of lines which converge towards a long wavelength value.

D. A set of lines which converge towards a high frequency value.

12. Which species has the same electron configuration as a Ca^{2+} ion?

A. Al^{3+} ion

B. Br^- ion

C. Ar atom

D. K atom

Chem 2/Q# 41//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

4. Which species represent a pair of isotopes?

Species	Number of protons	Number of electrons	Number of neutrons
L	12	12	12
M	13	13	13
P	13	10	13
Q	12	12	14

A. L and M

B. L and P

C. P and Q

D. L and Q

5. How many unpaired electrons are there in the Co^{2+} ion?

A. 7

B. 5

C. 3

D. 2

Chem 3/Q# 42//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

5. Successive ionization energies for an element, **Z**, are shown in the table below.

Electrons removed	1st	2nd	3rd	4th	5th
Ionization energy / kJ mol^{-1}	736	1450	7740	10 500	13 600

What is the most likely formula for the ion of **Z**?

A. Z^{+}

B. Z^{2+}

C. Z^{3+}

D. Z^{4+}

6. Which statements are correct for the oxides of period 3 going from Na to Cl?

I. The oxides become increasingly acidic.

II. The bonding of the oxides changes from ionic to covalent.

III. All the oxides dissolve readily in water.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

7. The elements argon, potassium, and calcium are consecutive in the periodic table. Which gives the correct order of **increasing** first ionization energies?

A. Ar < Ca < K

B. K < Ar < Ca

C. Ca < K < Ar

D. K < Ca < Ar

8. Cobalt forms the complex $[Co(NH_3)_5Cl]^{2+}$. Which statements are correct for this complex?

I. The cobalt ion acts as a Lewis acid.

II. The cobalt ion has an oxidation number of +II.

III. There are 90° bond angles between the cobalt ion and the ligands.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 3/Q# 43//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

6. Which equation represents the second ionization energy of potassium?

A. $K(g) \rightarrow K^{2+}(g) + 2e^-$

B. $K^+(g) \rightarrow K^{2+}(g) + e^-$

C. $K(s) \rightarrow K^{2+}(g) + 2e^-$

D. $K^+(s) \rightarrow K^{2+}(g) + e^-$

7. Which pair of elements shows the greatest difference in electronegativity?

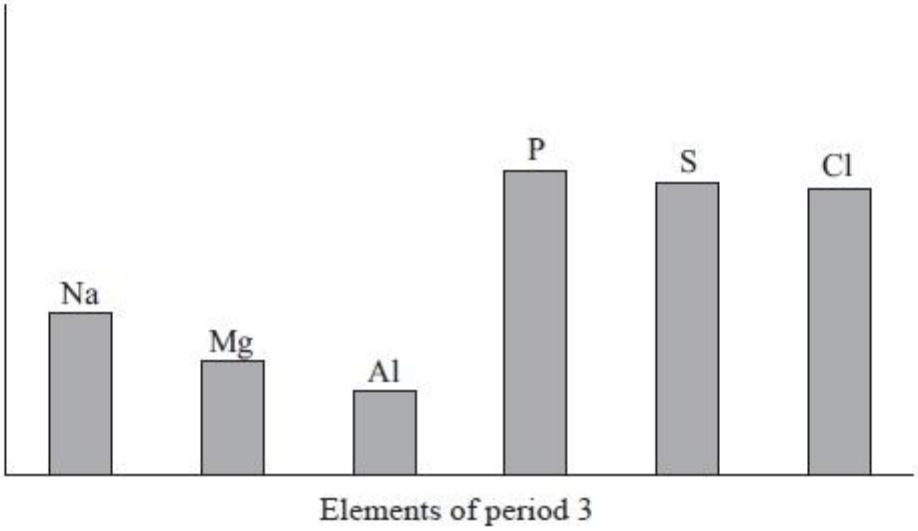
A. Mg and O

B. Li and F

C. K and F

D. Li and I

6. The horizontal axis of the bar chart represents the elements of period 3 from sodium to chlorine (excluding silicon). What could the vertical axis represent?



A. Melting point of the element

B. Electronegativity of the bonded atom

C. Ionic radius of the most common ion

D. First ionization energy in the gaseous state

7. Which statements about reactivity are correct?

I. Potassium reacts more vigorously than sodium with chlorine.

II. Lithium reacts more vigorously than potassium with water.

III. Fluorine reacts more vigorously than bromine with a potassium iodide solution.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

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

   A. $F < Cl^- < Cl$

   B. $Rb < K < Na$

   C. $Al^{3+} < Mg^{2+} < Na^+$

   D. $I^- < Br^- < Cl^-$

7. Which oxides form acidic solutions when added to water?

   A. $P_4O_{10}(s)$ and $SO_3(g)$

   B. $Na_2O(s)$ and $MgO(s)$

   C. $Al_2O_3(s)$ and $SiO_2(s)$

   D. $MgO(s)$ and $Al_2O_3(s)$

8. Which compound is likely to be colourless?

   A. $[Zn(H_2O)_6]Cl_2$

   B. $[NH_4]_2[Fe(H_2O)_6][SO_4]_2$

   C. $K_3[Co(CN)_6]$

   D. $[Ni(NH_3)_6][BF_4]_2$

9. What is the formula of calcium nitride?

   A. Ca_3N_2

   B. Ca_2N_3

   C. $Ca(NO_2)_2$

   D. $Ca(NO_3)_2$

7. Which statements are correct for the alkali metals Li to Cs?

I. Melting point increases

II. First ionization energy decreases

III. Ionic radius increases

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Which statements about $[Ag(NH_3)_2]^+$ are correct?

I. NH_3 forms a dative covalent (co-ordinate) bond with Ag^+.

II. The formation of the bond between NH_3 and Ag^+ is an example of a Lewis acid–base reaction.

III. Ag^+ is the ligand in this complex ion.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 3/Q# 47//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

6. Which statement concerning electronegativity is correct?

A. Electronegativity increases from left to right across a period.

B. Metals generally have higher electronegativity values than non-metals.

C. Electronegativity increases on descending a group.

D. Noble gases have the highest electronegativity values.

7. Which statements are correct?

I. Fluorine will react with potassium chloride solution to produce chlorine.

II. Iodine will react with sodium chloride solution to produce chlorine.

III. Bromine will react with lithium iodide solution to produce iodine.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Each of the following oxides is added to separate equal volumes of distilled water. Which of the following is the most acidic oxide?

A. P_4O_{10}

B. SO_3

C. Cl_2O_7

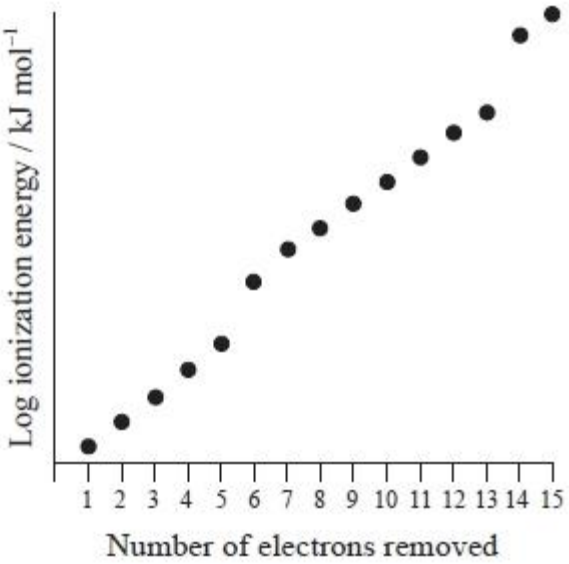
D. SiO_2

9. What are the correct formulas of the following ions?

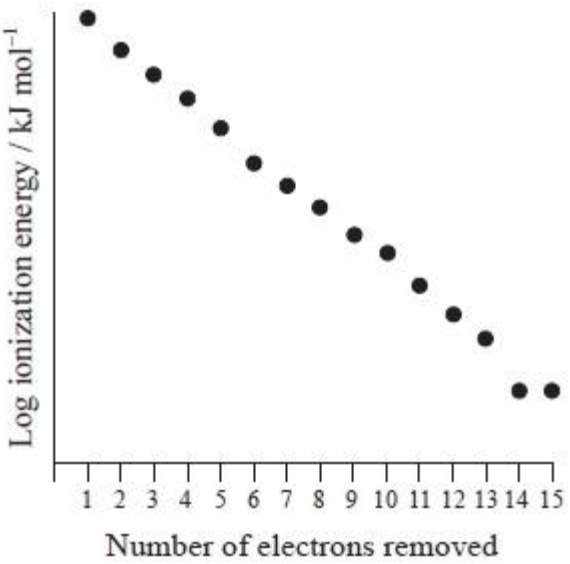
	Nitrate	Sulfate	Phosphate	Hydrogencarbonate
A.	NO_3^-	SO_4^{2-}	PO_4^{3-}	HCO_3^-
B.	NO_3^-	SO_4^{2-}	PO_3^{3-}	HCO_3^{2-}
C.	NO_2^-	SO_4^-	PO_4^{3-}	HCO_3^-
D.	NO_2^-	SO_3^{2-}	PO_3^{3-}	HCO_3^{2-}

5. Which of the graphs below shows the successive logarithmic ionization energies of phosphorus?

A.



B.



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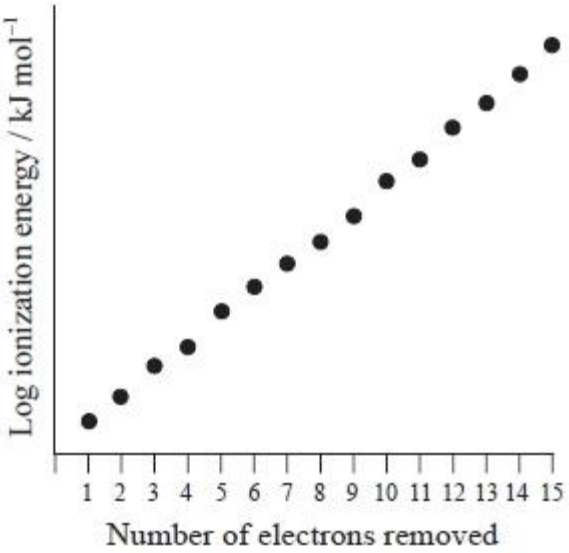
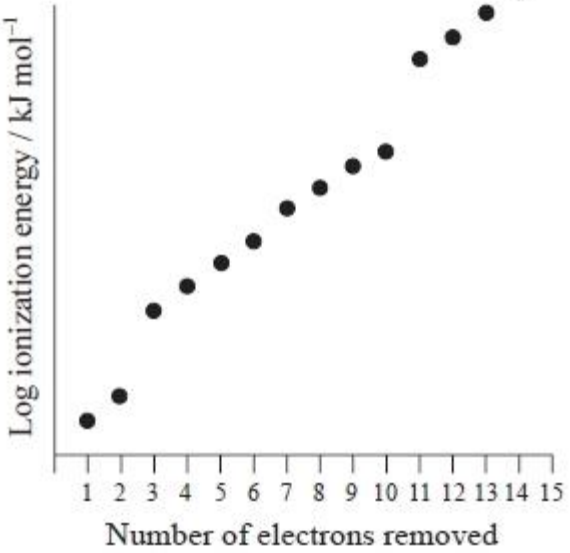


D.



6. Which combination is correct for the properties of the alkali metals from Li to Cs?

	Atomic radius	Melting point	First ionization energy
A.	increases	increases	increases
B.	increases	decreases	decreases
C.	increases	increases	decreases
D.	decreases	decreases	increases

7. Which equation represents a reaction that occurs under normal conditions?

A. $2LiBr(aq) + I_2(aq) \rightarrow 2LiI(aq) + Br_2(aq)$

B. $2KF(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + F_2(aq)$

C. $2LiCl(aq) + I_2(aq) \rightarrow 2LiI(aq) + Cl_2(aq)$

D. $2KBr(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + Br_2(aq)$

8. Which combination of statements about the oxides of period 3 elements is correct?

	State at room temperature			Electrical conductivity in molten state		
	Na_2O	Al_2O_3	P_4O_{10}	Na_2O	Al_2O_3	P_4O_{10}
A.	solid	solid	gas	good	good	good
B.	solid	solid	solid	good	good	poor
C.	solid	liquid	liquid	good	poor	poor
D.	solid	solid	solid	poor	poor	good

Chem 3/Q# 49//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

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

A. $Al^{3+} > Mg^{2+} > Na^{+} > F^{-}$

B. $F^{-} > Na^{+} > Mg^{2+} > Al^{3+}$

C. $F^{-} > Al^{3+} > Mg^{2+} > Na^{+}$

D. $Na^{+} > Mg^{2+} > Al^{3+} > F^{-}$

8. Which complex is colourless in solution?

A. $[Fe(H_2O)_6]Cl_2$

B. $[Ni(NH_3)_6]Cl_2$

C. $[Zn(H_2O)_6](NO_3)_2$

D. $K_3[Co(CN)_6]$

Chem 3/Q# 50//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

6. Which species are in the order of **increasing** ionic radius?

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

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

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

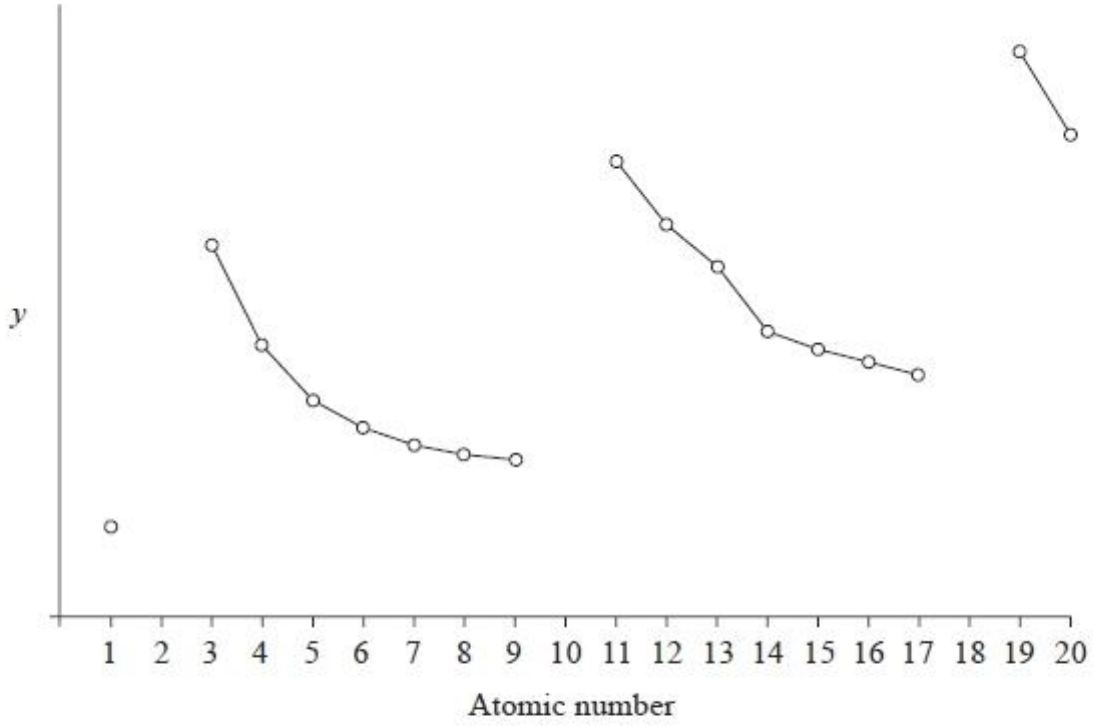
D. $S^{2-} < Cl^{-} < K^{+}$

Chem 3/Q# 51//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

7. Which combination of descriptions is correct for the oxides of period 3 elements?

	Chlorine	Magnesium	Silicon	Sodium
A.	basic	acidic	basic	acidic
B.	acidic	basic	basic	basic
C.	basic	acidic	acidic	acidic
D.	acidic	basic	acidic	basic

7. Which physical property of elements is represented by *y* on the graph below?



A. First ionization energy

B. Ionic radius

C. Atomic radius

D. Electronegativity

8. Which of the following redox reactions take place?

I. $Cl_2(aq) + 2NaI(aq) \rightarrow I_2(aq) + 2NaCl(aq)$

II. $Br_2(aq) + 2NaI(aq) \rightarrow I_2(aq) + 2NaBr(aq)$

III. $I_2(aq) + 2NaBr(aq) \rightarrow Br_2(aq) + 2NaI(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which metals are considered to be transition elements?

I. Ti

II. Zn

III. Fe

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 3/Q# 53//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

6. Values for the successive ionization energies for an unknown element are given in the table below.

First ionization energy / kJ mol^{-1}	Second ionization energy / kJ mol^{-1}	Third ionization energy / kJ mol^{-1}	Fourth ionization energy / kJ mol^{-1}
420	3600	4400	5900

In which group of the periodic table would the unknown element be found?

A. 1

B. 2

C. 3

D. 4

7. Which pair of elements has the greatest difference in electronegativity?

A. Cs and F

B. Cs and Cl

C. Cs and Br

D. Cs and I

8. Ligands can form dative covalent bonds with metal ions to form complex ions. Which of the following can act as a ligand?

I. Cl^-

II. NH_3

III. H_2O

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which metal nitrate solution is coloured?

A. $Zn(NO_3)_2(aq)$

B. $Ni(NO_3)_2(aq)$

C. $Mg(NO_3)_2(aq)$

D. $Sc(NO_3)_3(aq)$

7. Which property generally **decreases** across period 3?

   A. Atomic number

   B. Electronegativity

   C. Atomic radius

   D. First ionization energy

8. Which statement about the elements in group 7 is correct?

   A. Br_2 will oxidize Cl^-.

   B. F_2 has the least tendency to be reduced.

   C. Cl_2 will oxidize I^-.

   D. I_2 is a stronger oxidizing agent than F_2.

9. Which electron transitions are responsible for the colours of transition metal compounds?

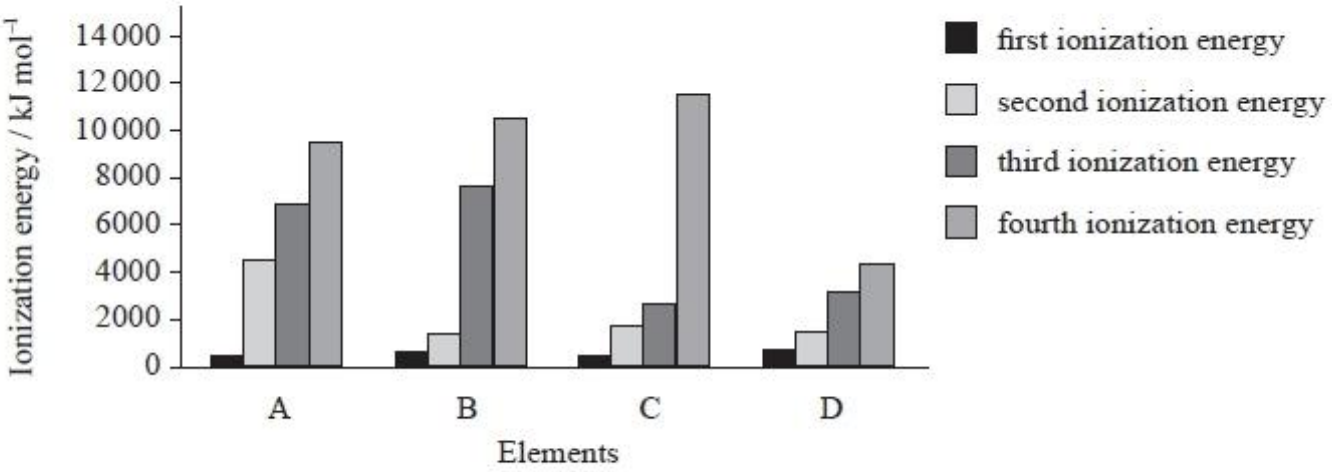
   A. Between d orbitals and s orbitals

   B. Among the attached ligands

   C. From the metal ion to the attached ligands

   D. Between d orbitals

5. The graph below shows the first four ionization energies of four elements A, B, C and D (the letters are not their chemical symbols). Which element is magnesium?



6. Which statements about the periodic table are correct?

I. The elements Mg, Ca and Sr have similar chemical properties.

II. Elements in the same period have the same number of main energy levels.

III. The oxides of Na, Mg and P are basic.

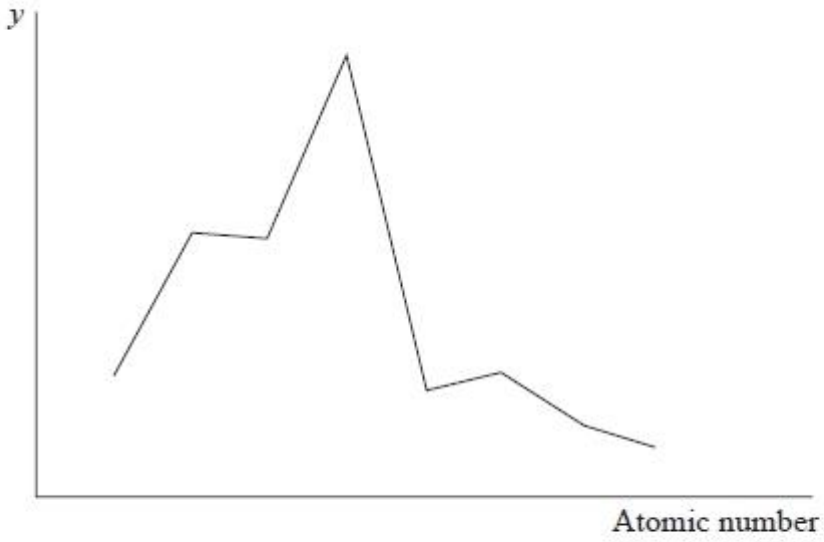
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

7. The x-axis of the graph below represents the atomic number of the elements in period 3.



Which variable could represent the y-axis?

A. Melting point

B. Electronegativity

C. Ionic radius

D. Atomic radius

8. In which complexes does iron have an oxidation number of +3?

I. $[Fe(H_2O)_6]^{3+}$

II. $[Fe(H_2O)_5(CN)]^{2+}$

III. $[Fe(CN)_6]^{3-}$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

6. Which ion has the largest radius?

A. Cl^-

B. K^+

C. Br^-

D. F^-

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

I. P_4O_{10}

II. MgO

III. SO_3

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. What is the ligand in the complex $K_3[Fe(CN)_6]$?

A. CN^-

B. Fe^{3+}

C. K^+

D. $[Fe(CN)_6]^{3-}$

7. Which statements about the periodic table are correct?

I. Elements in period 3 have similar chemical properties.

II. Elements in group 7 show a gradual change in physical properties.

III. The position of an element in period 3 is related to the number of electrons in the highest occupied energy level.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Which statements about period 3 are correct?

I. The oxides of the elements change from ionic to covalent across period 3.

II. The oxides of the elements change from basic to acidic across period 3.

III. First ionization energy of the elements increases linearly across period 3.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which statements are correct for the complex ion $[CuCl_4]^{2-}$?

I. The oxidation number of Cu in the complex ion is +2.

II. The coordination number of the copper ion is 4.

III. Chloride ions are behaving as ligands.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

6. Between which ionization energies of boron will there be the greatest difference?

A. Between 1st and 2nd ionization energies

B. Between 2nd and 3rd ionization energies

C. Between 3rd and 4th ionization energies

D. Between 4th and 5th ionization energies

7. What happens when sodium is added to water?

I. A gas is evolved

II. The temperature of the water increases

III. A clear, colourless solution is formed

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Which species has the largest radius?

A. Cl^-

B. K

C. Na^+

D. K^+

9. Which process is responsible for the colour of a transition metal complex?

A. The absorption of light when electrons move between s orbitals and d orbitals

B. The emission of light when electrons move between s orbitals and d orbitals

C. The absorption of light when electrons move between different d orbitals

D. The emission of light when electrons move between different d orbitals

Chem 3/Q# 59//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

8. Which statement describes the trends of electronegativity values in the periodic table?

A. Values increase from left to right across a period and increase down a group.

B. Values increase from left to right across a period and decrease down a group.

C. Values decrease from left to right across a period and increase down a group.

D. Values decrease from left to right across a period and decrease down a group.

9. Which equation best represents the first ionization energy of magnesium?

A. $Mg(s) \rightarrow Mg^{+}(s) + e^{-}$

B. $Mg(g) \rightarrow Mg^{2+}(g) + 2e^{-}$

C. $Mg(g) \rightarrow Mg^{+}(g) + e^{-}$

D. $Mg(s) \rightarrow Mg^{+}(g) + e^{-}$

10. What are the products of the reaction between chlorine and water?

A. O_2, H_2 and HCl

B. H_2 and OCl_2

C. HCl and HOCl

D. HOCl, H_2 and Cl_2

Chem 3/Q# 60//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

6. Which is the best definition of *electronegativity*?

A. Electronegativity is the energy required for a gaseous atom to gain an electron.

B. Electronegativity is the attraction of an atom for a bonding pair of electrons.

C. Electronegativity is the attraction between the nucleus and the valence electrons of an atom.

D. Electronegativity is the ability of an atom to attract electrons from another atom.

7. Which statements are correct for the reactions of Cl_2, $MgCl_2$ and $SiCl_4$ with water?

	Cl_2	$MgCl_2$	$SiCl_4$
A.	forms a neutral solution	forms a neutral solution	no reaction
B.	forms an acidic solution	forms an acidic solution	forms an acidic solution
C.	forms an acidic solution	forms an acidic solution	no reaction
D.	forms a neutral solution	forms a neutral solution	forms an acidic solution

8. Which transition element, or compound of a transition element, is used as a catalyst in the Contact process?

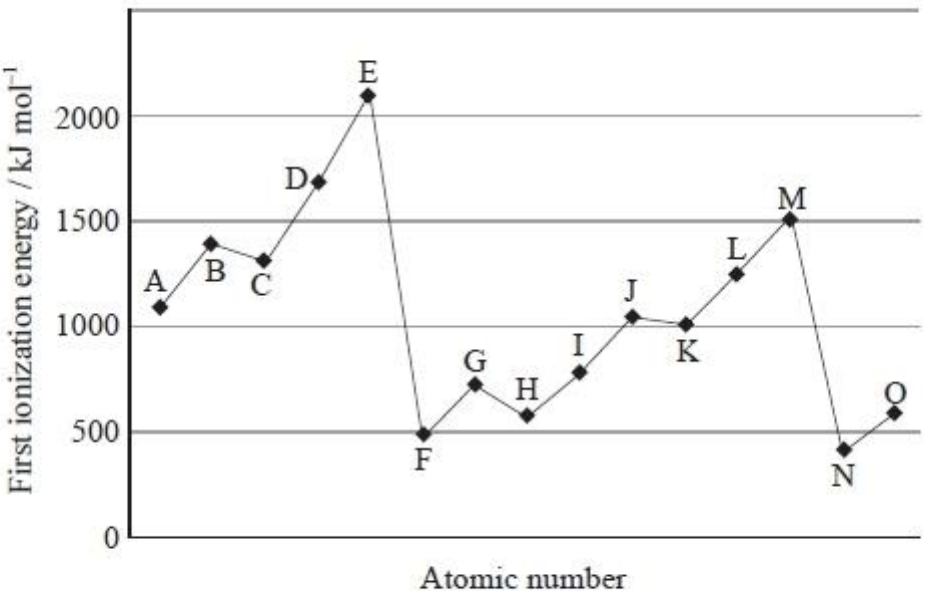
A. Fe

B. MnO_2

C. V_2O_5

D. Ni

4. The first ionization energies of successive elements in the periodic table are shown below.



Which statements are correct?

I. Elements E and M are in Group 0 of the periodic table.

II. Atoms of elements G and O have the outer electron configuration ns^2.

III. Atoms of elements B and J contain half-filled p orbitals.

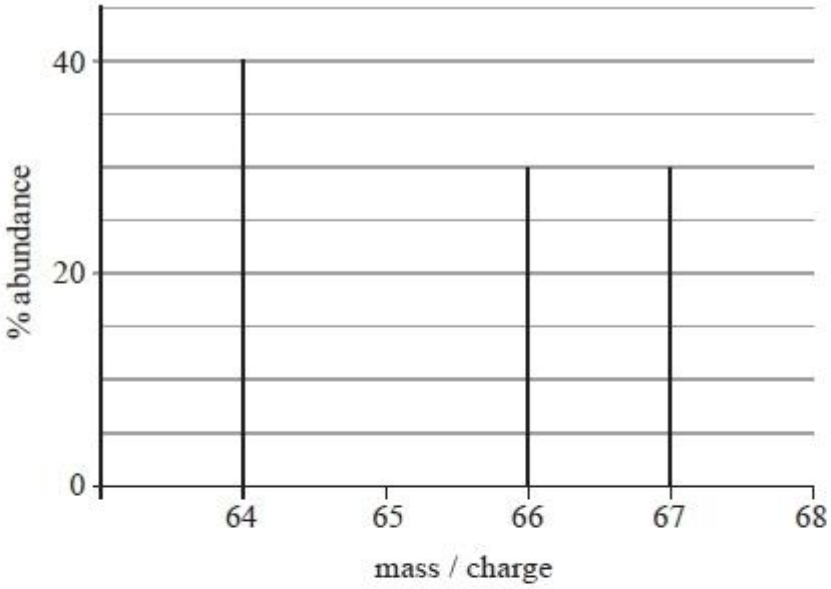
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

6. The mass spectrum of a sample of an element is shown below.



Which value is closest to the relative atomic mass of the element?

A. 64.5

B. 65.0

C. 65.5

D. 66.0

7. In what order are the elements listed in the periodic table?

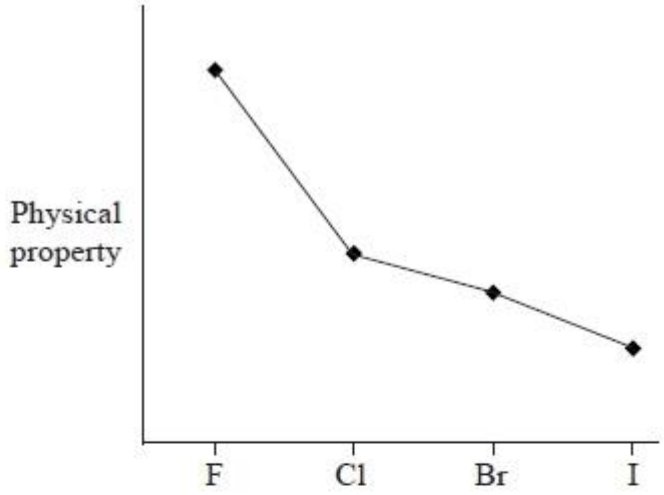
A. In order of relative atomic mass

B. In order of reactivity

C. In order of nuclear charge

D. In order of electronegativity

8. The graph shows the trend in a physical property down group 7 in the periodic table.



What is the physical property?

A. Atomic radius

B. Electronegativity

C. Density

D. Melting point

9. Which species can act as ligands with transition metal ions?

I. NH_3

II. Cl^-

III. CH_4

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. The table shows the boiling points of the hydrogen halides.

Compound	Boiling point / °C
HF	20
HCl	−85
HBr	−67
HI	−35

Which statement explains the higher boiling point of hydrogen fluoride?

A. The covalent bond in hydrogen fluoride is stronger than those in the other hydrogen halides.

B. There is strong hydrogen bonding between the hydrogen fluoride molecules.

C. Fluorine is the most reactive element in group 7.

D. Fluorine has the highest first ionization energy in group 7.

12. Which substance has the lowest electrical conductivity?

A. Al(s)

B. $Al_2O_3(l)$

C. KCl(aq)

D. HCl(g)

13. Which bond has the lowest polarity?

A. C−H in methane, CH_4

B. C=O in carbon dioxide, CO_2

C. C−C in ethane, C_2H_6

D. C−C in ethanol, C_2H_5OH

14. What is the correct description of hybridization present in buta-1,3-diene, $H_2C=CH-CH=CH_2$?

A. sp

B. sp^2

C. sp and sp^2

D. sp^3, sp^2 and sp

15. Which molecules contain a bond angle of 90°?

I. PF_5

II. $SiCl_4$

III. SF_6

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 3/Q# 64//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

5. Which statement about ionization energy is correct?

A. First ionization energies decrease across period 3.

B. Second ionization energies refer to the removal of two electrons from an atom.

C. Third ionization energies always involve the removal of an electron from a p-orbital.

D. The fourth ionization energy of an element is always greater than its third ionization energy.

7. Which properties vary in the same way down groups 1 and 7 of the periodic table?

I. Boiling points
II. Ionic radii
III. Atomic radii

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Which statements support the description of aluminium oxide as amphoteric?

I. It can show acidic behaviour in the presence of strong alkalis.
II. It can show alkaline behaviour in the presence of strong acids.
III. It dissolves in water to form a neutral solution.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which of these species involves the transition metal in one of its common oxidation states?

I. $Cr_2O_7^{2-}$
II. MnO_4^{3-}
III. $FeCl_3$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. What are the correct formulas of magnesium nitride and aluminium sulfide?

A. Mg_2N_3 and Al_2S_3

B. Mg_3N_2 and Al_2S_3

C. Mg_2N_3 and Al_3S_2

D. Mg_3N_2 and Al_3S_2

Chem 3/Q# 65//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

7. Which properties decrease in value when descending group 1?

I. Atomic radius
II. Ionization energy
III. Electronegativity

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. The ionization energies of three consecutive elements in the periodic table are 1680, 2080 and 494 $kJ\,mol^{-1}$ respectively. Which of the following shows the elements with these values?

A. O F Ne

B. F Ne Na

C. Ne Na Mg

D. Na Mg Al

9. Which comparison of radii of atoms and ions is correct?

A. $Cl^- > Cl$

B. $H^+ > H^-$

C. $Na^+ > Na$

D. $Mg^{2+} > Mg^+$

10. Which trend is correct when the elements are considered from left to right across period 3?

A. The acidic character of the oxides decreases.

B. The electrical conductivity of the elements increases.

C. The bonding of the chlorides changes from ionic to covalent.

D. Electronegativity decreases.

Chem 4/Q# 66//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

9. Which species contains a dative covalent (coordinate) bond?

A. HCN

B. C_2H_2

C. CO_2

D. CO

10. Which sequence has the molecules in order of increasing nitrogen-nitrogen bond length?

A. $N_2 < N_2H_4 < N_2H_2$

B. $N_2 < N_2H_2 < N_2H_4$

C. $N_2H_4 < N_2H_2 < N_2$

D. $N_2H_2 < N_2H_4 < N_2$

11. Which process involves the breaking of hydrogen bonds?

A. $2HI(g) \rightarrow H_2(g) + I_2(g)$

B. $CH_4(g) \rightarrow C(g) + 4H(g)$

C. $H_2(l) \rightarrow H_2(g)$

D. $NH_3(l) \rightarrow NH_3(g)$

12. What is the correct number of sigma (σ) and pi (π) bonds in prop-2-enenitrile, CH_2CHCN?

	σ bonds	π bonds
A.	7	2
B.	4	5
C.	6	3
D.	3	3

13. Which group of ions and molecules has delocalized electrons in **all** the species?

A. CH_3COCH_3, $C_2H_5COO^-$ and O_3

B. NO_3^-, NO_2^- and CO_2

C. C_6H_6, CO_3^{2-} and graphite

D. C_6H_6, CO_3^{2-} and C_2H_2

Chem 4/Q# 67//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

9. Which properties do typical ionic compounds have?

	Melting point	Conductivity of solid
A.	high	good
B.	low	good
C.	high	poor
D.	low	poor

10. What is the difference between the strength and the length of the carbon-oxygen bond in butanal and in butan-1-ol?

A. The bond in butanal is stronger and longer than in butan-1-ol.

B. The bond in butanal is weaker and shorter than in butan-1-ol.

C. The bond in butanal is weaker and longer than in butan-1-ol.

D. The bond in butanal is stronger and shorter than in butan-1-ol.

11. Which allotropes of carbon show sp^2 hybridization?

I. Diamond

II. Graphite

III. C_{60} fullerene

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

12. Which molecule is trigonal bipyramidal in shape?

A. PCl_3

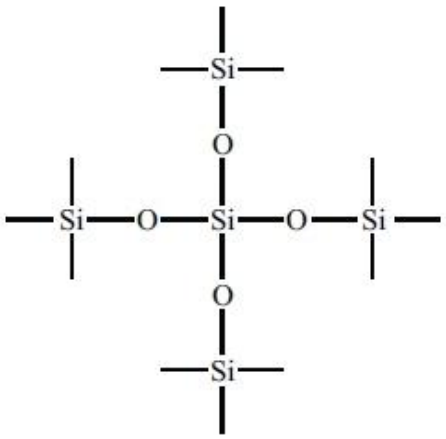
B. $SiCl_4$

C. PCl_5

D. SF_6

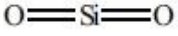
13. Which diagram represents the bonding in SiO_2?

A.

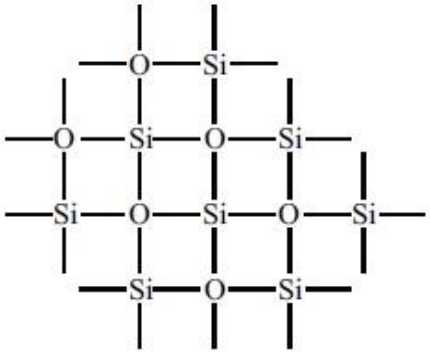


B.

C.



D.



8. Which ion is colourless?

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

B. $[Cr(H_2O)_6]^{3+}$

C. $[Fe(H_2O)_6]^{3+}$

D. $[Fe(CN)_6]^{3-}$

9. The electronegativities of four elements are given in the table.

Element	W	X	Y	Z
Electronegativity	0.9	1.1	3.4	4.0

Which statement is correct?

A. W and X form an ionic compound.

B. W and X form a covalent compound.

C. Y and Z form an ionic compound.

D. Y and Z form a covalent compound.

10. Which combination of length and strength of the carbon–to–carbon bonds in C_2H_2 and C_2H_4 is correct?

	Bond length	**Bond strength**
A.	$C_2H_2 > C_2H_4$	$C_2H_2 < C_2H_4$
B.	$C_2H_2 > C_2H_4$	$C_2H_2 > C_2H_4$
C.	$C_2H_2 < C_2H_4$	$C_2H_2 < C_2H_4$
D.	$C_2H_2 < C_2H_4$	$C_2H_2 > C_2H_4$

10. Which combination of length and strength of the carbon–to–carbon bonds in C_2H_2 and C_2H_4 is correct?

	Bond length	Bond strength
A.	$C_2H_2 > C_2H_4$	$C_2H_2 < C_2H_4$
B.	$C_2H_2 > C_2H_4$	$C_2H_2 > C_2H_4$
C.	$C_2H_2 < C_2H_4$	$C_2H_2 < C_2H_4$
D.	$C_2H_2 < C_2H_4$	$C_2H_2 > C_2H_4$

11. A solid has a melting point of 1582 °C and does not dissolve in water. It does not conduct electricity in the molten state. What type of structure does the solid have?

A. Ionic

B. Metallic

C. Giant molecular

D. Simple molecular

12. The diagrams below show *s* and *p* orbitals in different positions. Which combinations can form a σ-bond?

I.

II.

III.

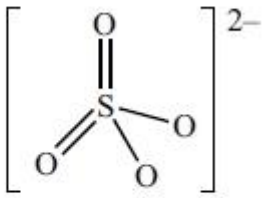
A. I and II only

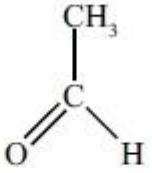
B. I and III only

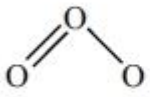
C. II and III only

D. I, II and III

13. Which species contain delocalized electrons?

I. 

II. 

III. 

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

10. Which compounds have an ionic lattice structure in the solid state?

I. Silicon dioxide

II. Sodium fluoride

III. Ammonium nitrate

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which intermolecular forces exist between the following molecules?

	H_2Se	CO	H_2
A.	van der Waals' and dipole-dipole	van der Waals' and dipole-dipole	van der Waals' only
B.	van der Waals', dipole-dipole and hydrogen bonding	van der Waals' only	van der Waals' and hydrogen bonding
C.	van der Waals', dipole-dipole and hydrogen bonding	van der Waals' and dipole-dipole	van der Waals' only
D.	van der Waals' and dipole-dipole	van der Waals' and dipole-dipole	van der Waals' and hydrogen bonding

12. Which species have dative covalent bonding?

I. $[Fe(H_2O)_6]Cl_3$

II. NH_4^+

III. H_2O

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

13. How many sigma (σ) and pi (π) bonds are there in $CH_3CH_2CCCH_2COOH$?

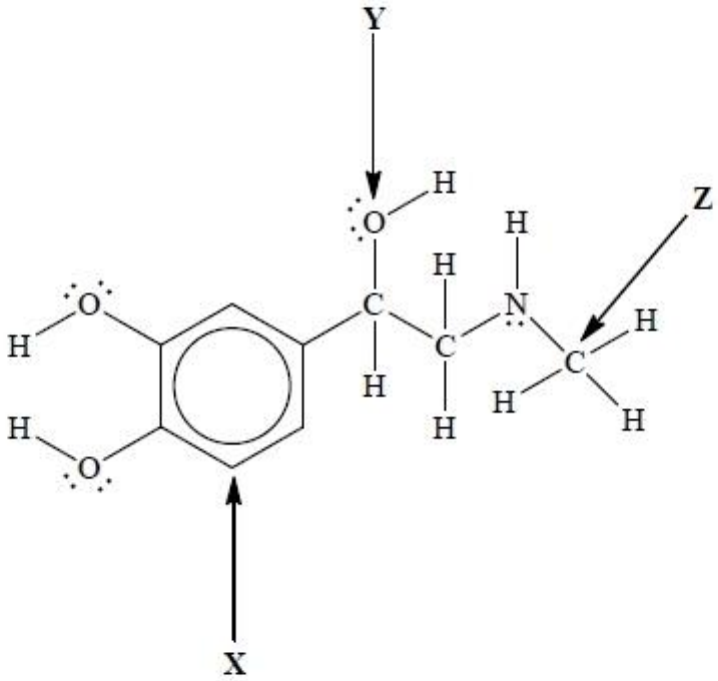
A. 13σ and 5π

B. 15σ and 2π

C. 15σ and 3π

D. 15σ only

14. What is the hybridization of atoms **X**, **Y** and **Z** in epinephrine?



	X	Y	Z
A.	sp^2	sp^3	sp^3
B.	sp^2	sp	sp^3
C.	sp^3	sp^2	sp^2
D.	sp^3	sp^3	sp^3

Chem 4/Q# 71//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

25. Which compound has the highest enthalpy of vaporization?

A. CO_2

B. NH_3

C. H_2S

D. H_2O

Chem 4/Q# 72//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

9. Which is the best description of a metallic bond?

A. Electrostatic attraction between oppositely charged ions

B. Electrostatic attraction between a pair of electrons and positively charged nuclei

C. Electrostatic attraction between a lattice of positive ions and delocalized electrons

D. Electrostatic attraction for a bonding pair of electrons which have been supplied by one of the atoms

10. Which statements about the structure and bonding of silicon dioxide are correct?

	Structure	Bonding
A.	Silicon dioxide forms a giant covalent network.	Each oxygen atom is covalently bonded to two silicon atoms.
B.	Silicon dioxide molecules are V-shaped or bent.	Each silicon atom is covalently bonded to two oxygen atoms.
C.	Silicon dioxide molecules are linear.	A double covalent bond exists between silicon and oxygen atoms.
D.	Silicon dioxide forms a giant covalent network.	Each oxygen atom is covalently bonded to four silicon atoms.

11. Which series shows **increasing** boiling points?

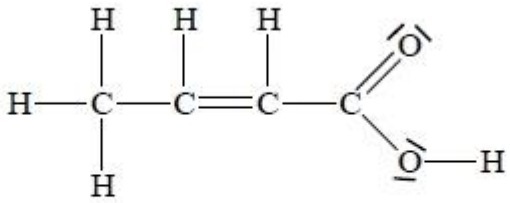
A. $CH_3CH_2CH_3 < CH_3CH_2OH < CH_3CHO$

B. $CH_3CHO < CH_3CH_2CH_3 < CH_3CH_2OH$

C. $CH_3CH_2OH < CH_3CHO < CH_3CH_2CH_3$

D. $CH_3CH_2CH_3 < CH_3CHO < CH_3CH_2OH$

12. How many sigma (σ) and pi (π) bonds are there in the following molecule?



	σ bonds	π bonds
A.	9	2
B.	9	4
C.	11	2
D.	11	4

13. Which species have delocalized π electrons?

I. CH_3COCH_3

II. NO_2^-

III. CO_3^{2-}

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 4/Q# 73//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

10. Which compound is predominantly covalent?

A. LiCl

B. Al_2O_3

C. ClF

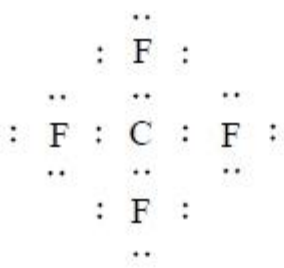
D. $ZnCl_2$

11. Which combination best describes the type of bonding present and the melting point of silicon and silicon dioxide?

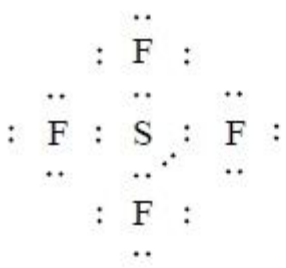
	Silicon		Silicon dioxide	
A.	covalent bonding	high melting point	covalent bonding	high melting point
B.	metallic bonding	high melting point	covalent bonding	low melting point
C.	ionic bonding	high melting point	ionic bonding	low melting point
D.	covalent bonding	low melting point	ionic bonding	high melting point

12. Which species has a square planar shape?

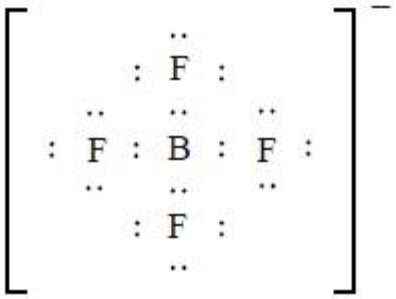
A.



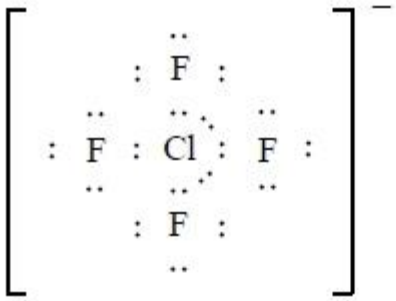
B.



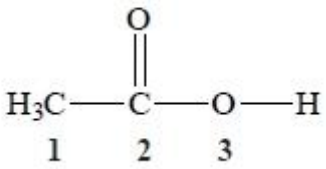
C.



D.



13. What are the hybridizations of the atoms labelled 1, 2 and 3 in the molecule below?



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

Chem 4/Q# 75//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

9. Which is an ionic compound?

A. Mg_3N_2

B. Al_2Cl_6

C. SiO_2

D. SF_6

10. Which molecule is polar?

	Molecule	Shape
A.	CO_2	linear
B.	SO_3	trigonal planar
C.	CCl_4	tetrahedral
D.	SO_2	bent (V-shaped)

11. Which intermolecular forces are present in HI(l)?

I. Hydrogen bonding

II. Dipole-dipole forces

III. Van der Waals' (London dispersion) forces

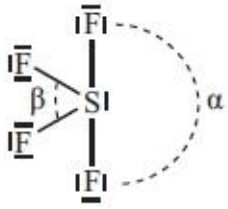
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

12. In the molecule SF_4, which are the correct bond angles?



	α / °	β / °
A.	180	120
B.	187	103
C.	187	120
D.	180	90

13. Which substances have delocalized electrons in their structure?

I. Ethanal

II. Ozone

III. Benzene

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which species contain dative covalent bonds?

I. CO

II. NH_3

III. H_3O^+

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

10. Which single covalent bond is the most polar, given the following electronegativity values?

Element	H	C	S	O
Electronegativity	2.2	2.6	2.6	3.4

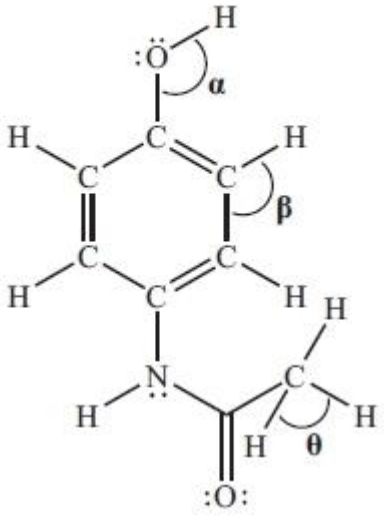
A. C–O

B. S–H

C. C–H

D. O–H

11. The Lewis (electron dot) structure of paracetamol (acetaminophen) is:



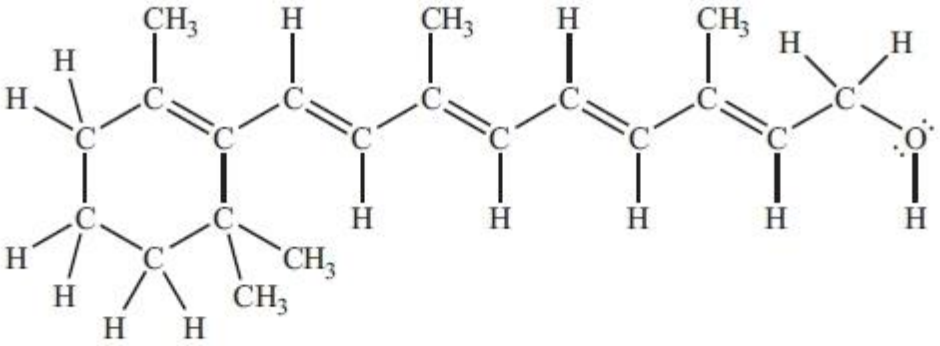
What are the approximate values of the bond angles?

	α	β	θ
A.	104.5°	120°	109.5°
B.	109.5°	109.5°	109.5°
C.	120°	120°	90°
D.	104.5°	120°	90°

12. Which types of intermolecular forces exist in HBr, Cl_2 and CH_3F?

	HBr	Cl_2	CH_3F
A.	van der Waals' and dipole-dipole	van der Waals' only	van der Waals' and dipole-dipole
B.	van der Waals' and dipole-dipole	van der Waals' only	van der Waals', dipole-dipole and hydrogen bonding
C.	van der Waals' only	van der Waals' only	van der Waals', dipole-dipole and hydrogen bonding
D.	van der Waals' and dipole-dipole	van der Waals' and dipole-dipole	van der Waals', dipole-dipole and hydrogen bonding

13. Retinol (vitamin A) contains a total of **5** double bonds and **46** single bonds.



Which statements are correct?

I. There are 51 σ and 5 π bonds.

II. The oxygen atom is sp^3 hybridized.

III. Retinol is a primary alcohol.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

14. Zinc metal contains metallic bonding. Which is the best description of a metallic bond?

A. The electrostatic attraction between a pair of electrons and positively charged nuclei.

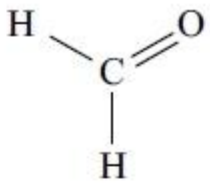
B. The electrostatic attraction between oppositely charged ions.

C. The electrostatic attraction between a lattice of positive ions and delocalized electrons.

D. The bond formed when one atom provides both electrons in a shared pair.

Chem 4/Q# 77//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

9. What is the correct number of centres of negative charge for carbon and the shape of H_2CO?



	Centres of negative charge on C-atom	Shape
A.	3	trigonal pyramidal
B.	3	trigonal planar
C.	4	trigonal pyramidal
D.	4	trigonal planar

10. Which statement about intermolecular forces is correct?

A. The intermolecular force between H_2 molecules is hydrogen bonding, because H_2 has temporary dipoles.

B. The intermolecular forces between PH_3 molecules are greater than the intermolecular forces between NH_3 molecules, because they have a greater mass.

C. The intermolecular force between H_2 molecules is hydrogen bonding, because H_2 has permanent dipoles.

D. The intermolecular forces between Br_2 molecules are van der Waals', because Br_2 has temporary dipoles.

11. Which substances are soluble in hexane, C_6H_{14}?

I. C_8H_{18}

II. CH_4

III. H_2O

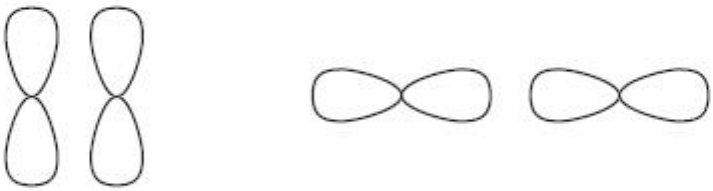
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

12. Diagrams **I** and **II** show two p orbitals on adjacent atoms in different relative orientations.



I **II**

Which types of bonds are formed when the orbitals overlap?

	Orientation I	Orientation II
A.	σ	σ
B.	π	π
C.	π	σ
D.	σ	π

13. Which molecules have delocalized π electrons?

I. C_6H_6

II. CH_3COOH

III. O_3

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 4/Q# 78//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

10. When C_2H_2, C_2H_4 and C_2H_6 are arranged in order of **increasing** carbon-carbon bond strength (weakest bond first), what is the correct order?

A. C_2H_2, C_2H_4, C_2H_6

B. C_2H_2, C_2H_6, C_2H_4

C. C_2H_6, C_2H_4, C_2H_2

D. C_2H_6, C_2H_2, C_2H_4

11. Which molecule has a non-bonding (lone) pair of electrons around the central atom?

A. BF_3

B. SO_2

C. PCl_5

D. SiF_4

12. Which particles are responsible for the conduction of electricity in molten aluminium?

A. Cations

B. Anions

C. Electrons

D. Protons

13. How many sigma and pi bonds are there in propyne, CH_3CCH?

A. 2 sigma and 2 pi

B. 7 sigma and 1 pi

C. 6 sigma and 2 pi

D. 5 sigma and 3 pi

14. Which species does **not** have delocalized electrons?

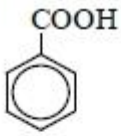
A. NO_3^-

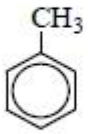
B. NO_2^-

C. O_3

D. C_3H_6

15. In which compound are all the carbon atoms sp^2 hybridized?

A. 

B. 

C. CH_2CHCH_3

D. $CH_3CH_2CHCHCH_2CH_3$

10. How many σ and π bonds are present in a molecule of propyne, CH_3CCH?

	σ	π
A.	5	3
B.	6	2
C.	7	1
D.	8	0

11. Which species does **not** contain delocalized electrons?

A. $CH_3CH_2O^-$

B. $CH_3CO_2^-$

C. O_3

D. NO_3^-

12. Which compound forms hydrogen bonds in the liquid state?

A. C_2H_5OH

B. $CHCl_3$

C. CH_3CHO

D. $(CH_3CH_2)_3N$

13. Which particles are responsible for electrical conductivity in metals?

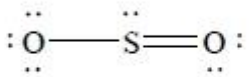
A. Anions

B. Cations

C. Electrons

D. Protons

14. The Lewis structure of SO_2 is given below.



What is the shape of the SO_2 molecule?

A. Bent (V-shaped)

B. Linear

C. T-shaped

D. Triangular planar

9. The electronegativities of four different elements are given below (the letters are not their chemical symbols).

Element	W	X	Y	Z
Electronegativity	0.9	1.2	3.4	4.0

Based on this information which statement is correct?

A. W is a non-metal.

B. W and X form an ionic compound.

C. Y is a metal.

D. Y and Z form a covalent compound.

10. Which species contain a dative covalent bond?

I. HCHO

II. CO

III. H_3O^+

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which substance is made up of a lattice of positive ions and free moving electrons?

A. Graphite

B. Sodium chloride

C. Sulfur

D. Sodium

12. Which molecule has an octahedral shape?

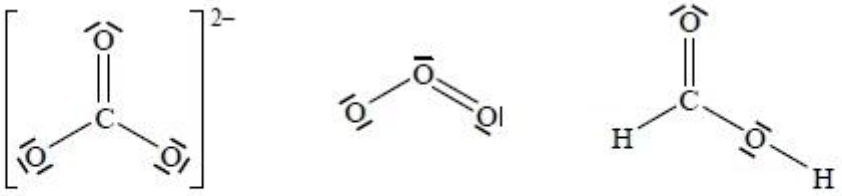
A. SF_6

B. PCl_5

C. XeF_4

D. BF_3

13. Which species have delocalized electrons?



I II III

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which species have a dative covalent bond?

I. CO
II. NH_3
III. H_3O^+

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

10. Which substance can form intermolecular hydrogen bonds in the liquid state?

A. CH_3OCH_3

B. CH_3CH_2OH

C. CH_3CHO

D. $CH_3CH_2CH_3$

11. Which molecule is polar?

A. CH_2Cl_2

B. BCl_3

C. Cl_2

D. CCl_4

12. The Lewis structure of XeF_2 contains two bonding pairs of electrons and three non-bonding pairs of electrons (lone pairs) around the central xenon atom. What is the shape of XeF_2 molecule?

A. Bent

B. Trigonal bipyramidal

C. Square planar

D. Linear

13. How many sigma (σ) bonds are present in $(CH_3)_2C{=}CClCH_2CH_3$?

A. 1

B. 4

C. 16

D. 17

Chem 4/Q# 82//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

10. Which molecule has the shortest carbon-oxygen bond length?

A. CH_3COOH

B. CH_3CH_2OH

C. CO_2

D. CO

11. Which pair of compounds is arranged in correct order of relative boiling points?

	Lower Boiling Point	Higher Boiling Point
A.	CH_3OCH_3	CH_3CH_2OH
B.	CH_3CHO	$CH_3CH_2CH_3$
C.	CH_3CH_2OH	CH_3CHO
D.	CH_3COOH	CH_3CH_2OH

12. Which intermolecular forces exist between molecules of carbon monoxide, CO?

A. Hydrogen bonds and van der Waals' forces

B. Dipole-dipole attractions and van der Waals' forces

C. Van der Waals' forces only

D. Dipole-dipole attractions only

13. Which statements about σ and π bonds are correct?

I. σ bonds result from the axial overlap of orbitals.

II. σ bonds only form from s orbitals.

III. π bonds result from the sideways overlap of parallel p orbitals.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

14. In which substance does a carbon atom have sp^2 hybridization?

A. 2-methylbutan-1-ol

B. Propyne, CH_3CCH

C. C_{60} fullerene

D. Diamond

Chem 4/Q# 83//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

10. What is the correct order if the compounds are arranged in order of increasing boiling point?

A. $CH_4 < CH_3Cl < SiH_4 < CH_3OH$

B. $CH_3OH < CH_4 < CH_3Cl < SiH_4$

C. $CH_3OH < CH_3Cl < SiH_4 < CH_4$

D. $CH_4 < SiH_4 < CH_3Cl < CH_3OH$

11. What is the bond angle in the H_3O^+ ion?

A. 104°

B. 107°

C. 109°

D. 120°

12. Which compound does **not** form hydrogen bonds between its molecules?

A. CH_3NH_2

B. CH_3COCH_3

C. CH_3COOH

D. CH_3CH_2OH

13. How many atoms is each carbon directly bonded to in its allotropes?

	Diamond	Graphite	C_{60} fullerene
A.	3	3	3
B.	4	3	3
C.	4	3	4
D.	4	4	3

14. What is the type of hybridization of the silicon and oxygen atoms in silicon dioxide?

	Silicon	Oxygen
A.	sp^3	sp^3
B.	sp^3	sp^2
C.	sp^2	sp^3
D.	sp^2	sp^2

Chem 4/Q# 84//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

11. Which statement best describes the **intramolecular** bonding in HCN(l)?

A. Electrostatic attractions between H^+ and CN^- ions

B. Only van der Waals' forces

C. Van der Waals' forces and hydrogen bonding

D. Electrostatic attractions between pairs of electrons and positively charged nuclei

12. How many bonding pairs and lone pairs of electrons surround the sulfur atom in the SF_4 molecule?

	Bonding pairs	Lone pairs
A.	4	1
B.	4	0
C.	6	0
D.	8	2

13. Metal M has only one oxidation number and forms a compound with the formula MCO_3. Which formula is correct?

A. MNO_3

B. MNH_4

C. MSO_4

D. MPO_4

14. Which of the following best describes the formation of π bonds?

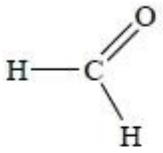
A. They are formed by the sideways overlap of parallel orbitals.

B. They are formed by the axial overlap of orbitals.

C. They are formed by the sideways overlap of an s and p orbital.

D. They are formed by the axial overlap of either s or p orbitals.

15. What is the hybridization of the carbon atom, and the number of σ and π bonds in the methanal molecule?



	Hybridization	σ bonds	π bonds
A.	sp^2	3	1
B.	sp^3	3	1
C.	sp^3	4	0
D.	sp^2	4	0

Chem 4/Q# 85//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

9. Which is the best description of ionic bonding?

A. The electrostatic attraction between positively charged nuclei and an electron pair

B. The electrostatic attraction between positive ions and delocalized negative ions

C. The electrostatic attraction between positive ions and delocalized electrons

D. The electrostatic attraction between oppositely charged ions

10. Which statements best describe the structure of sodium chloride, NaCl?

I. Each sodium ion is surrounded by six chloride ions.

II. The chloride ions are arranged octahedrally around each sodium ion.

III. The lattice forms a cubic structure.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which molecule contains a dative covalent (coordinate) bond?

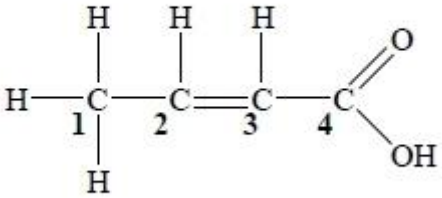
A. HCN

B. H_2O_2

C. CO_2

D. CO

12. Identify the hybridization of carbon atoms in this molecule



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

13. Which structure has delocalized π electrons?

A. O_3

B. CO

C. HCN

D. CO_2

Chem 4/Q# 86//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

13. When are ionic bonds most likely to form?

A. When two elements with high electronegativity values react with each other.

B. When two metals of different groups react with each other.

C. When two non metallic elements react with each other.

D. When a metal and a non metal react with each other.

14. What is the shape of PF_5?

A. Tetrahedral

B. Trigonal pyramidal

C. Square planar

D. Trigonal bipyramidal

15. The formula of tetrachloromethane is CCl_4. Which combination correctly shows the number of lone pairs of electrons in the Lewis structure, the shape of the molecule and the type of hybridization of the carbon atom?

	Lone pairs of electrons in Lewis Structure	Shape of molecule	Type of hybridization
A.	4	pyramidal	sp^2
B.	8	square planar	sp^2
C.	12	tetrahedral	sp^3
D.	16	tetrahedral	sp^3

11. Which substance will **not** conduct an electric current?

A. C(s) (graphite)

B. NaF(l)

C. CaO(s)

D. KI(aq)

12. Which of the following liquids is non-polar?

A. Water

B. Hexane

C. Propanone

D. Ethanol

13. The following substances all contain a nitrogen to nitrogen bond: N_2, N_2H_4, N_2H_2. Which shows them in **increasing** order of nitrogen to nitrogen bond length (smallest first)?

A. N_2H_4, N_2H_2, N_2

B. N_2, N_2H_2, N_2H_4

C. N_2H_2, N_2H_4, N_2

D. N_2H_4, N_2, N_2H_2

14. What is the bond angle in NO_3^-?

A. 107°

B. 109.5°

C. 120°

D. 180°

14. Consider the following equations.

$$2Fe(s)+1\tfrac{1}{2}O_2(g) \rightarrow Fe_2O_3(s) \qquad \Delta H^{\ominus} = x$$
$$CO(g)+\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = y$$

What is the enthalpy change of the reaction below?

$$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$$

A. $3y - x$

B. $3y + x$

C. $-3y - x$

D. $-3y + x$

15. Consider the following bond enthalpy data.

Bond	Bond enthalpy / kJ mol^{-1}
H–H	436
Cl–Cl	243
H–Cl	432

What is the enthalpy change, in kJ mol^{-1}, of this reaction?

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

A. +247

B. –247

C. –185

D. +185

16. Which processes have a negative value for $\Delta S^{\ominus}$?

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

II. $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

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

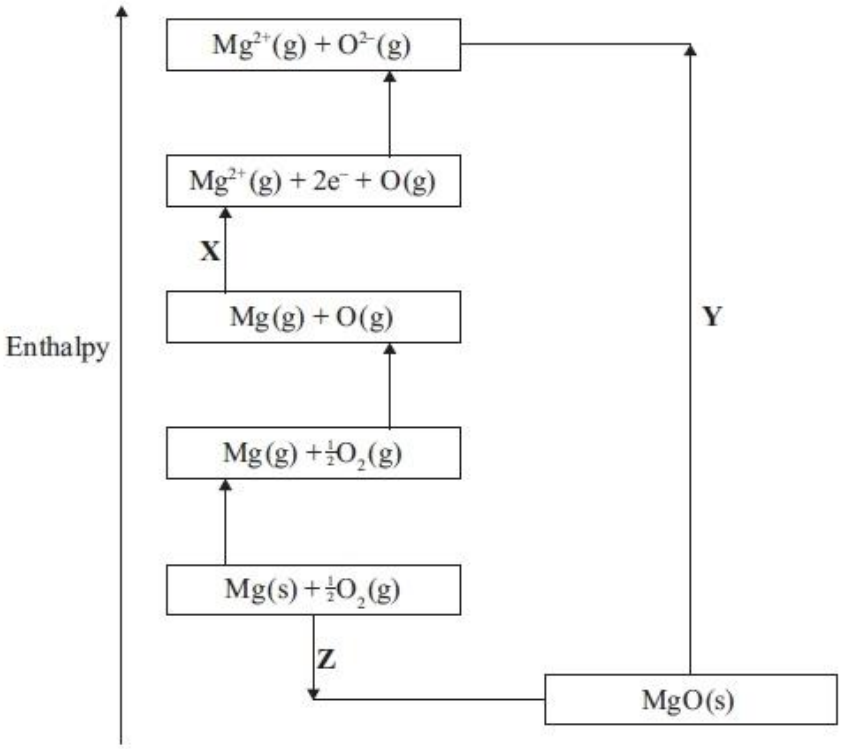
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

17. The Born–Haber cycle for the formation of magnesium oxide is shown below.



What is a correct description of the steps **X**, **Y** and **Z** in this cycle?

	Step X	Step Y	Step Z
A.	2nd ionization energy of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO
B.	2nd ionization energy of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
C.	sum of the 1st and 2nd ionization energies of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
D.	sum of 1st and 2nd ionization energies of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO

18. Consider the values of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for the reaction of nitrogen with oxygen at 298 K.

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H^{\ominus} = +181\,kJ\,mol^{-1}$$
$$\Delta S^{\ominus} = +25\,JK^{-1}mol^{-1}$$

Which statement is correct for this reaction?

A. $\Delta G^{\ominus}$ is positive at all temperatures.

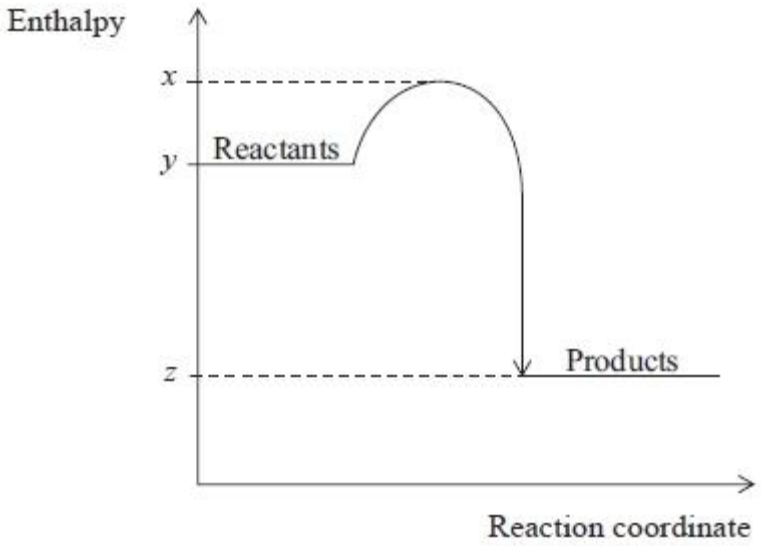
B. $\Delta G^{\ominus}$ is negative at all temperatures.

C. $\Delta G^{\ominus}$ is positive at high temperatures.

D. $\Delta G^{\ominus}$ is positive at low temperatures.

Chem 5/Q# 89//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

14. What is the value of ΔH for the exothermic reaction represented by the diagram below?



A. $y - z$

B. $z - y$

C. $x - z$

D. $z - x$

15. Which combination of enthalpy change and entropy change produces a non-spontaneous reaction at **all** temperatures?

	ΔH	ΔS
A.	+	−
B.	+	+
C.	−	−
D.	−	+

16. Which equation represents the lattice enthalpy of calcium chloride?

A. $CaCl(s) \rightarrow Ca^{+}(g) + Cl^{-}(g)$

B. $CaCl_2(s) \rightarrow Ca^{2+}(g) + 2Cl^{-}(g)$

C. $CaCl_2(g) \rightarrow Ca^{2+}(g) + 2Cl^{-}(g)$

D. $CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^{-}(aq)$

17. In which reaction will the entropy of the system increase significantly?

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

B. $H_2O(g) \rightarrow H_2O(l)$

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

D. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

18. Which equation represents the second electron affinity of oxygen?

A. $\frac{1}{2}O_2(g) + 2e^{-} \rightarrow O^{2-}(g)$

B. $O(g) + 2e^{-} \rightarrow O^{2-}(g)$

C. $O_2(g) + 4e^{-} \rightarrow 2O^{2-}(g)$

D. $O^{-}(g) + e^{-} \rightarrow O^{2-}(g)$

19. What is the temperature rise when 2100 J of energy is supplied to 100 g of water? (Specific heat capacity of water = $4.2\,J\,g^{-1}\,K^{-1}$.)

A. 5 °C

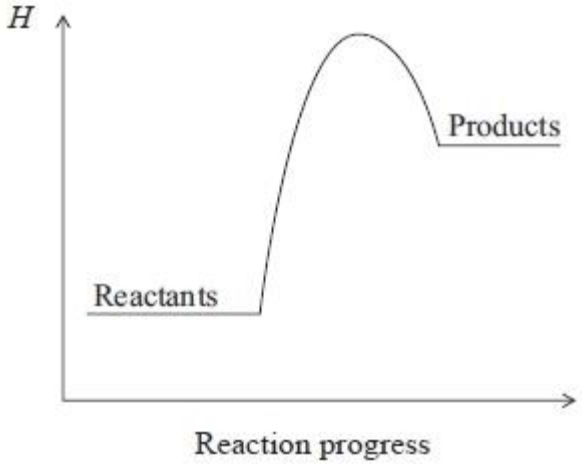
B. 278 K

C. 0.2 °C

D. 20 °C

Chem 5/Q# 90//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

14. Which statement is correct for the reaction with this enthalpy level diagram?



A. Heat energy is released during the reaction and the reactants are more stable than the products.

B. Heat energy is absorbed during the reaction and the reactants are more stable than the products.

C. Heat energy is released during the reaction and the products are more stable than the reactants.

D. Heat energy is absorbed during the reaction and the products are more stable than the reactants.

15. The enthalpy changes of three reactions are given below.

$$2HCOOH(l) + O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \qquad \Delta H = a$$

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H = b$$

$$2HCOOC_2H_5(l) + 7O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \qquad \Delta H = c$$

What is the enthalpy change for the following reaction?

$$HCOOH(l) + C_2H_5OH(l) \rightarrow HCOOC_2H_5(l) + H_2O(l)$$

A. $a+b+c$

B. $a+2b-c$

C. $\frac{1}{2}a+b+\frac{1}{2}c$

D. $\frac{1}{2}a+b-\frac{1}{2}c$

16. What is the correct definition of lattice enthalpy?

A. Enthalpy change when one mole of a solid ionic compound is separated into gaseous ions.

B. Enthalpy change when one mole of a solid ionic compound is separated into its ions in their standard state.

C. Enthalpy change when one mole of a solid ionic compound is formed from gaseous elements.

D. Enthalpy change when one mole of a compound is formed from the elements in their standard states.

17. Which reaction has the greatest increase in entropy?

A. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

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

C. $2HCl(aq) + MgCO_3(s) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$

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

18. Which change **must** be negative when a reaction occurs spontaneously?

A. ΔH

B. ΔG

C. ΔS

D. ΔT

Chem 5/Q# 91//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

15. Which processes are exothermic?

I. $CH_3CH_2CH_3(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

II. $Cl_2(g) \rightarrow 2Cl(g)$

III. $CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow CH_3CH_2COONa(aq) + H_2O(l)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Consider the following two equations.

$$2Ca(s) + O_2(g) \rightarrow 2CaO(s) \qquad \Delta H^{\ominus} = +x \text{ kJ}$$

$$Ca(s) + 0.5O_2(g) + CO_2(g) \rightarrow CaCO_3(s) \qquad \Delta H^{\ominus} = +y \text{ kJ}$$

What is $\Delta H^{\ominus}$, in kJ, for the following reaction?

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

A. $y - 0.5x$

B. $y - x$

C. $0.5 - y$

D. $x - y$

17. Which ionic compound has the most endothermic lattice enthalpy?

A. Sodium chloride

B. Sodium oxide

C. Magnesium chloride

D. Magnesium oxide

18. Which processes are predicted to have a positive entropy change, ΔS?

I. $I_2(g) \rightarrow I_2(s)$

II. $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

III. $CH_3OH(l) \rightarrow CH_3OH(g)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

19. Which combination of ΔH and ΔS signs will always result in a spontaneous reaction at all temperatures?

	ΔH	ΔS
A.	+	+
B.	+	–
C.	–	–
D.	–	+

14. The specific heat capacity of aluminium is $0.900\,J\,g^{-1}\,K^{-1}$. What is the heat energy change, in J, when 10.0 g of aluminium is heated and its temperature increases from 15.0 °C to 35.0 °C?

A. +180

B. +315

C. +1800

D. +2637

15. Enthalpy changes of reaction are provided for the following reactions.

$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^{\ominus} = +52\,kJ\,mol^{-1}$$
$$2C(s) + 3H_2(g) \rightarrow C_2H_6(g) \qquad \Delta H^{\ominus} = -85\,kJ\,mol^{-1}$$

What is the enthalpy change, in $kJ\,mol^{-1}$, for the reaction between ethene and hydrogen?

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$$

A. −137

B. −33

C. +33

D. +137

16. Which reaction has an enthalpy change equal to the standard enthalpy change of combustion?

A. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

B. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

C. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

D. $C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

17. Which reactions/processes have a positive entropy change, $\Delta S^{\ominus}$?

I. $NaCl(s) \rightarrow NaCl(aq)$

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

III. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18. Which compound has the most positive lattice enthalpy of dissociation?

A. NaCl

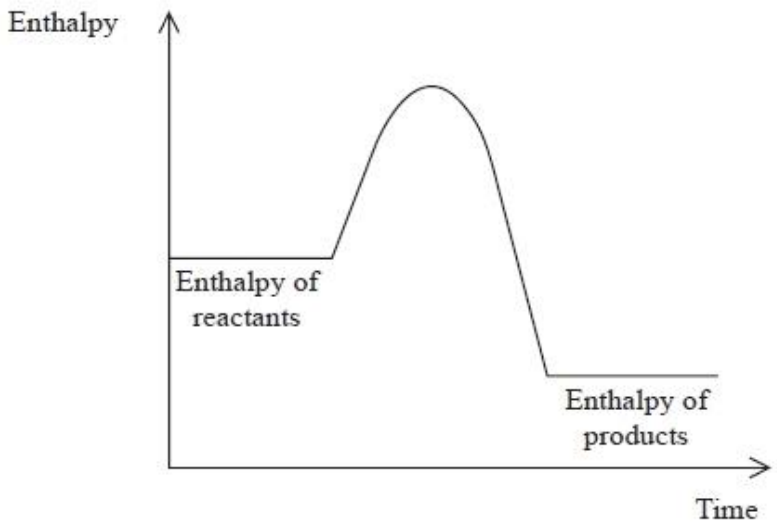
B. NaBr

C. $MgCl_2$

D. $MgBr_2$

Chem 5/Q# 93//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

14. Which statement is correct for the enthalpy level diagram shown?



A. The reaction is exothermic and the products are more stable than the reactants.

B. The reaction is exothermic and the sign of the enthalpy change is positive.

C. The reaction is endothermic and the sign of the enthalpy change is negative.

D. The reaction is endothermic and the products are more stable than the reactants.

15. Which process is endothermic?

A. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

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

C. $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D. $NH_3(g) \rightarrow NH_3(l)$

16. Which combination of ions will give the greatest absolute lattice enthalpy?

A. A small positive ion with a high charge and a small negative ion with a high charge

B. A small positive ion with a low charge and a small negative ion with a low charge

C. A large positive ion with a high charge and a large negative ion with a high charge

D. A large positive ion with a low charge and a small negative ion with a low charge

17. Which process would be expected to have a $\Delta S^\ominus$ value which is negative?

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

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

C. $H_2(g) + I_2(g) \rightarrow 2HI(g)$

D. $OF_2(g) + H_2O(g) \rightarrow O_2(g) + 2HF(g)$

18. When solid potassium chlorate, $KClO_3$, dissolves in distilled water the temperature of the solution decreases. What are the signs of $\Delta H^\ominus$, $\Delta S^\ominus$ and $\Delta G^\ominus$ for this spontaneous process?

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

14. A 5.00 g sample of a substance was heated from 25.0 °C to 35.0 °C using 2.00×10^2 J of energy. What is the specific heat capacity of the substance in J g^{-1} K^{-1}?

A. 4.00×10^{-3}

B. 2.50×10^{-1}

C. 2.00

D. 4.00

15. Using the equations below:

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -390 \text{ kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -286 \text{ kJ}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H^{\ominus} = -890 \text{ kJ}$$

what is $\Delta H^{\ominus}$, in kJ, for the following reaction?

$$C(s) + 2H_2(g) \rightarrow CH_4(g)$$

A. −214

B. −72

C. +72

D. +214

16. Which is the best definition of electron affinity?

A. The ability of an atom to attract the electrons in a covalent bond.

B. The attraction of an atom for an electron.

C. The enthalpy change when an atom gains an electron.

D. The enthalpy change when a gaseous atom gains an electron.

17. Which is the best definition of the standard state?

A. The standard state of a solid is the most pure form of the solid.

B. The standard state of a solid is the most pure form of the solid at 298 °C.

C. The standard state of a gas is the most pure form of the gas at 298 °C.

D. The standard state of a gas is the most pure form of the gas at a pressure of 100 kPa.

18. Consider the following information:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$
$$\Delta H = +179\ kJ\,mol^{-1}$$
$$\Delta S = +161.0\ J\,K^{-1}\,mol^{-1}$$

What happens to the spontaneity of this reaction as the temperature is increased?

A. The reaction becomes more spontaneous as the temperature is increased.

B. The reaction becomes less spontaneous as the temperature is increased.

C. The reaction remains spontaneous at all temperatures.

D. The reaction remains non-spontaneous at all temperatures.

19. Which piece of equipment could **not** be used in an experiment to measure the rate of this reaction?

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

A. A colorimeter

B. A gas syringe

C. A stopwatch

D. A pH meter

Chem 5/Q# 95//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

14. What are the units for specific heat capacity?

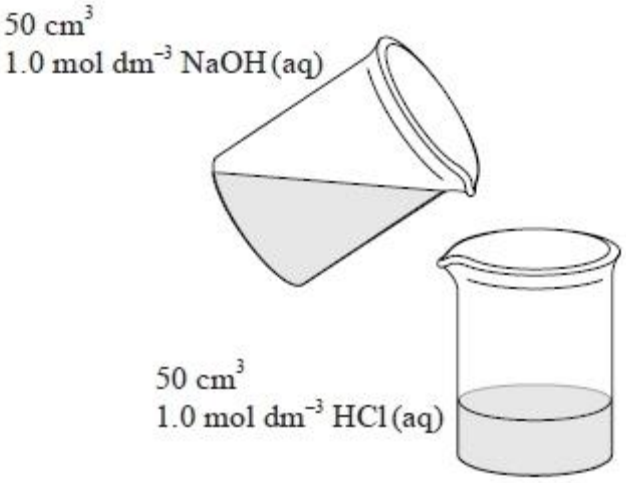
A. kJ kg K

B. $kJ\,kg\,K^{-1}$

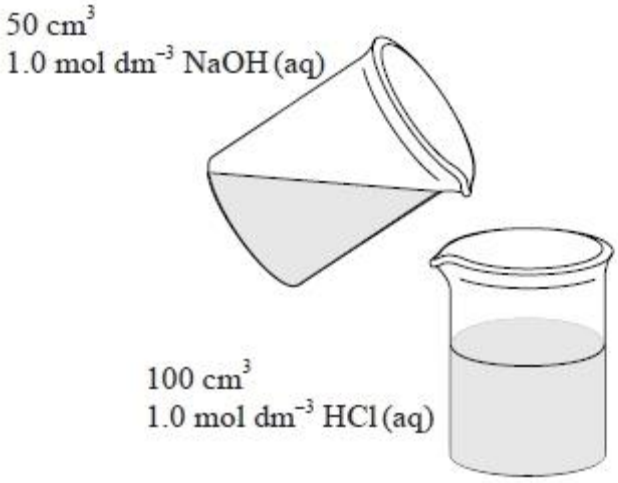
C. $kJ\,kg^{-1}\,K$

D. $kJ\,kg^{-1}\,K^{-1}$

15. In each of two different experiments, A and B, a solution of sodium hydroxide is added to a solution of hydrochloric acid. The initial temperature of each solution is 25 °C.



Experiment A



Experiment B

Which statement is correct?

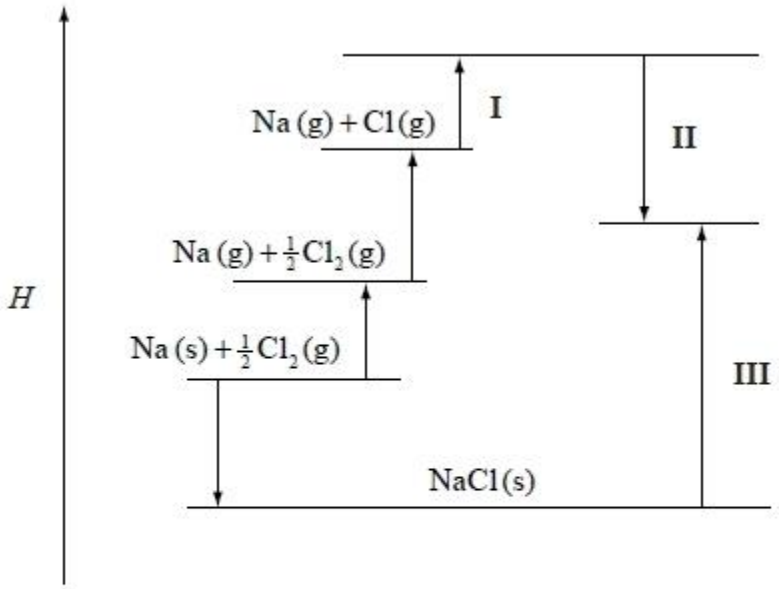
A. The highest recorded temperature of experiment A is lower than the highest recorded temperature of experiment B.

B. The highest recorded temperature of both experiments is equal.

C. The heat produced in experiment A is lower than the heat produced in experiment B.

D. The heat produced in both experiments is equal.

16. The diagram represents the Born–Haber cycle for the lattice enthalpy of sodium chloride.



What is the name of the enthalpy changes **I**, **II** and **III**?

	I	II	III
A.	ionization energy of Na	electron affinity of Cl	lattice enthalpy of NaCl
B.	lattice enthalpy of NaCl	ionization energy of Na	electron affinity of Cl
C.	electron affinity of Cl	ionization energy of Na	lattice enthalpy of NaCl
D.	ionization energy of Na	lattice enthalpy of NaCl	electron affinity of Cl

17. Which statements about entropy for the following reaction at 298 K are correct?

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

I. $S^{\ominus}(O_2) = 0$

II. $\Delta S^{\ominus} = 2S^{\ominus}(NO_2) - 2S^{\ominus}(NO) - S^{\ominus}(O_2)$

III. $\Delta S^{\ominus} < 0$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18. Which reaction is spontaneous at high temperatures, but not at low temperatures?

A. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta H < 0$

B. $CaCO_3(s) \rightarrow CO_2(g) + CaO(s)$ $\Delta H > 0$

C. $Fe(s) + Cl_2(g) \rightarrow FeCl_2(s)$ $\Delta H < 0$

D. $2C(s) + 2H_2O(g) \rightarrow CH_3COOH(l)$ $\Delta H > 0$

Chem 5/Q# 96//**IB/Paper 1/2011/w/Time Zone 0/Higher Level/**

10. Which bonds are arranged in order of **increasing** polarity?

A. H–F < H–Cl < H–Br < H–I

B. H–I < H–Br < H–F < H–Cl

C. H–I < H–Br < H–Cl < H–F

D. H–Br < H–I < H–Cl < H–F

11. Which row correctly describes the bonding type and melting point of carbon and carbon dioxide?

	Carbon		Carbon dioxide	
A.	covalent bonding	high melting point	covalent bonding	low melting point
B.	ionic bonding	low melting point	ionic bonding	high melting point
C.	ionic bonding	high melting point	ionic bonding	low melting point
D.	covalent bonding	low melting point	covalent bonding	high melting point

12. What is the correct order of **increasing** boiling points?

A. $CH_3CH_3 < CH_3CH_2Cl < CH_3CH_2Br < CH_3CH_2I$

B. $CH_3CH_2Cl < CH_3CH_2Br < CH_3CH_3 < CH_3CH_2I$

C. $CH_3CH_2I < CH_3CH_2Br < CH_3CH_2Cl < CH_3CH_3$

D. $CH_3CH_2Br < CH_3CH_2Cl < CH_3CH_2I < CH_3CH_3$

13. What are the correct formulas of the following ions?

	Nitrate	Phosphate	Carbonate	Ammonium
A.	NO_3^-	PO_4^{3-}	CO_3^-	NH_3^+
B.	NO_3^{2-}	PO_3^{2-}	CO_3^{2-}	NH_3^+
C.	NO_3^-	PO_4^{3-}	CO_3^{2-}	NH_4^+
D.	NO_3^{2-}	PO_3^{2-}	CO_3^{2-}	NH_4^+

14. Which statements about hybridization are correct?

I. The hybridization of carbon in diamond is sp^3.

II. The hybridization of carbon in graphite is sp^2.

III. The hybridization of carbon in C_{60} fullerene is sp^3.

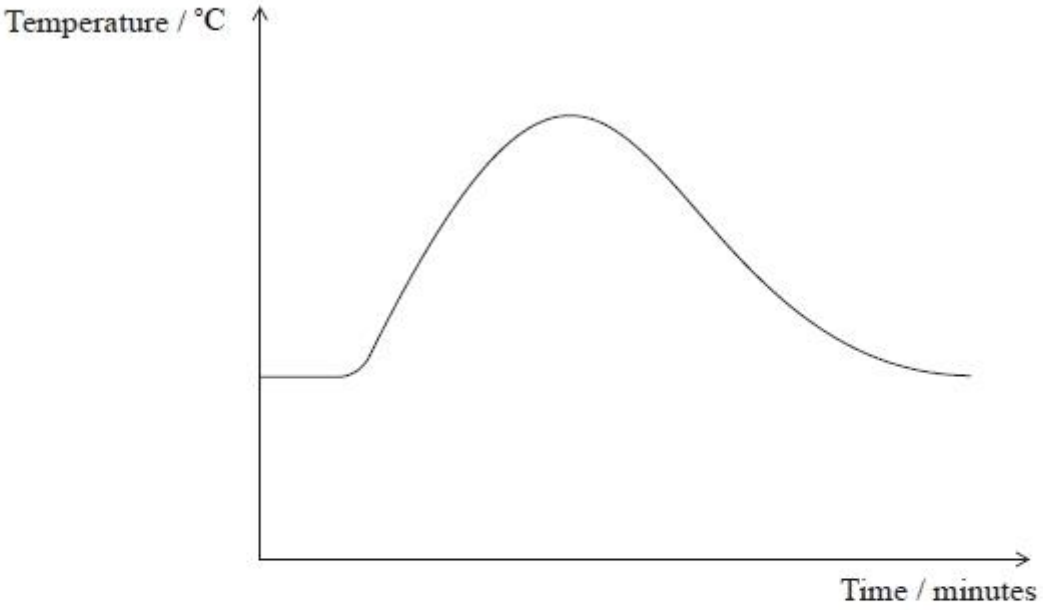
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

15. A student measured the temperature of a reaction mixture over time using a temperature probe. By considering the graph, which of the following deductions can be made?



I. The reaction is exothermic.

II. The products are more stable than the reactants.

III. The reactant bonds are stronger than the product bonds.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Consider the following enthalpy of combustion data.

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

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -y \text{ kJ mol}^{-1}$$

$$C_2H_6(g) + 3\tfrac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H^{\ominus} = -z \text{ kJ mol}^{-1}$$

What is the enthalpy of formation of ethane in kJ mol^{-1}?

$$2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$$

A. $[(-x) + (-y)] - (-z)$

B. $(-z) - [(-x) + (-y)]$

C. $[(-2x) + (-3y)] - (-z)$

D. $(-z) - [(-2x) + (-3y)]$

17. Which row of the table correctly represents the equations for the lattice enthalpy of substance XY and the electron affinity of atom Y?

	Lattice enthalpy	Electron affinity
A.	$X^+(g) + Y^-(g) \rightarrow XY(g)$	$Y^-(g) + e^- \rightarrow Y^{2-}(g)$
B.	$X^+(g) + Y^-(g) \rightarrow XY(s)$	$Y(g) + e^- \rightarrow Y^-(g)$
C.	$X^+(g) + Y^-(g) \rightarrow XY(s)$	$Y(s) + e^- \rightarrow Y^-(s)$
D.	$X^+(g) + Y^-(g) \rightarrow XY(g)$	$Y(g) + e^- \rightarrow Y^-(g)$

18. Which factors will increase the entropy of this system?

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

I. Increasing the temperature without changing the volume of the container.

II. Decreasing the concentration of the gas without changing the volume of the container.

III. Increasing the pressure without changing the volume of the container.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Which ionic compound has the greatest lattice enthalpy?

A. MgO

B. CaO

C. NaF

D. KF

17. Which equation represents the bond enthalpy for the H–Br bond in hydrogen bromide?

A. $HBr(g) \rightarrow H(g) + Br(g)$

B. $HBr(g) \rightarrow H(g) + Br(l)$

C. $HBr(g) \rightarrow H(g) + \frac{1}{2}Br_2(l)$

D. $HBr(g) \rightarrow H(g) + \frac{1}{2}Br_2(g)$

18. Which change will **not** increase the entropy of a system?

A. Increasing the temperature

B. Changing the state from liquid to gas

C. Mixing different types of particles

D. A reaction where four moles of gaseous reactants changes to two moles of gaseous products

19. $\Delta G^{\ominus}$ calculations predict that a reaction is always spontaneous for which of the following combinations of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$?

A. $+\Delta H^{\ominus}$ and $+\Delta S^{\ominus}$

B. $+\Delta H^{\ominus}$ and $-\Delta S^{\ominus}$

C. $-\Delta H^{\ominus}$ and $-\Delta S^{\ominus}$

D. $-\Delta H^{\ominus}$ and $+\Delta S^{\ominus}$

15. When hydrogen peroxide decomposes, the temperature of the reaction mixture increases.

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$$

What are the signs of ΔH, ΔS and ΔG for this reaction?

	ΔH	ΔS	ΔG
A.	–	–	–
B.	–	+	–
C.	+	+	–
D.	–	+	+

16. Which reaction has the greatest increase in entropy?

A. $SO_2(g) + 2H_2S(g) \rightarrow 2H_2O(l) + 3S(s)$

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

C. $CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + C_2H_2(g)$

D. $N_2(g) + O_2(g) \rightarrow 2NO(g)$

17. Consider the two reactions involving iron and oxygen.

$$2Fe(s) + O_2(g) \rightarrow 2FeO(s) \qquad \Delta H^{\ominus} = -544 \text{ kJ}$$
$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \qquad \Delta H^{\ominus} = -1648 \text{ kJ}$$

What is the enthalpy change, in kJ, for the reaction below?

$$4FeO(s) + O_2(g) \rightarrow 2Fe_2O_3(s)$$

A. –1648 – 2(–544)

B. –544 – (–1648)

C. –1648 – 544

D. –1648 – 2(544)

18. Which statement about bonding is correct?

A. Bond breaking is endothermic and requires energy.

B. Bond breaking is endothermic and releases energy.

C. Bond making is exothermic and requires energy.

D. Bond making is endothermic and releases energy.

19. Which equation corresponds to the lattice enthalpy for silver iodide, AgI?

A. $AgI(s) \rightarrow Ag(s) + I(g)$

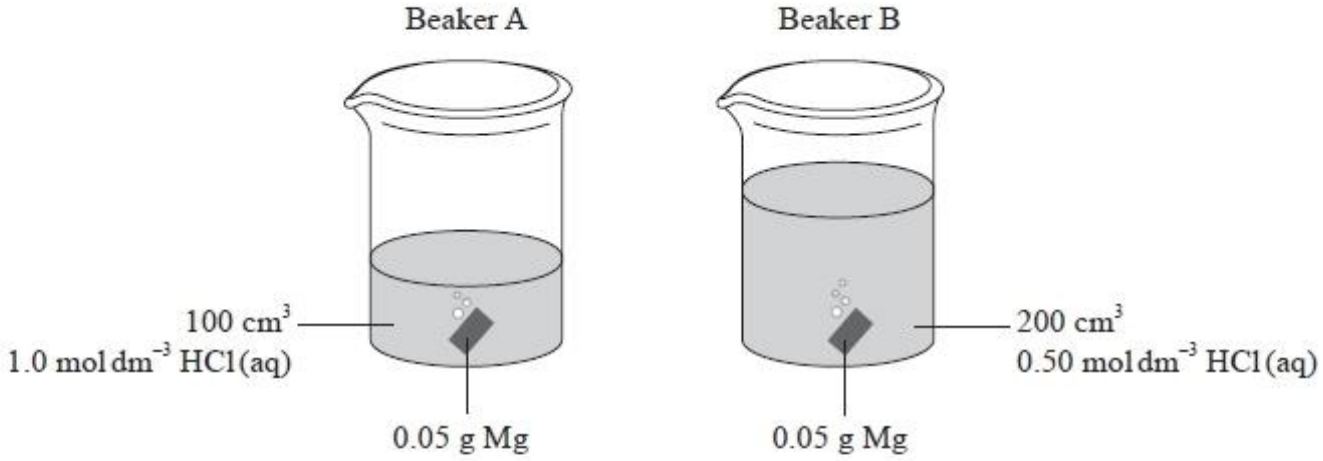
B. $AgI(s) \rightarrow Ag(s) + \frac{1}{2}I_2(g)$

C. $AgI(s) \rightarrow Ag^+(aq) + I^-(aq)$

D. $AgI(s) \rightarrow Ag^+(g) + I^-(g)$

Chem 5/Q# 100//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

14. Identical pieces of magnesium are added to two beakers, A and B, containing hydrochloric acid. Both acids have the same initial temperature but their volumes and concentrations differ.



Which statement is correct?

A. The maximum temperature in A will be higher than in B.

B. The maximum temperature in A and B will be equal.

C. It is not possible to predict whether A or B will have the higher maximum temperature.

D. The temperature in A and B will increase at the same rate.

15. Consider the equations below.

$$CH_4(g) + O_2(g) \rightarrow HCHO(l) + H_2O(l) \qquad \Delta H^{\ominus} = x$$

$$HCHO(l) + \tfrac{1}{2}O_2(g) \rightarrow HCOOH(l) \qquad \Delta H^{\ominus} = y$$

$$2HCOOH(l) + \tfrac{1}{2}O_2(g) \rightarrow (COOH)_2(s) + H_2O(l) \qquad \Delta H^{\ominus} = z$$

What is the enthalpy change of the reaction below?

$$2CH_4(g) + 3\tfrac{1}{2}O_2(g) \rightarrow (COOH)_2(s) + 3H_2O(l)$$

A. $x + y + z$

B. $2x + y + z$

C. $2x + 2y + z$

D. $2x + 2y + 2z$

16. Given the enthalpy change for the reaction below:

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

which statement is correct?

A. The standard enthalpy change of combustion of $H_2(g)$ is -286 kJ mol^{-1}.

B. The standard enthalpy change of combustion of $H_2(g)$ is $+286 \text{ kJ mol}^{-1}$.

C. The standard enthalpy change of formation of $H_2O(l)$ is -572 kJ mol^{-1}.

D. The standard enthalpy change of formation of $H_2O(l)$ is $+572 \text{ kJ mol}^{-1}$.

17. Which is a correct definition of lattice enthalpy?

A. It is the enthalpy change that occurs when an electron is removed from 1 mol of gaseous atoms.

B. It is the enthalpy change that occurs when 1 mol of a compound is formed from its elements.

C. It is the enthalpy change that occurs when 1 mol of solid crystal changes into a liquid.

D. It is the enthalpy change that occurs when 1 mol of solid crystal is formed from its gaseous ions.

18. Which reaction has the largest increase in entropy?

A. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

B. $Al(OH)_3(s) + NaOH(aq) \rightarrow Al(OH)_4^-(aq) + Na^+(aq)$

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

D. $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$

Chem 5/Q# 101//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

14. Which processes are exothermic?

I. Ice melting

II. Neutralization

III. Combustion

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

15. The standard enthalpy changes for the combustion of carbon and carbon monoxide are shown below.

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

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H_c^{\ominus} = -283 \text{ kJ mol}^{-1}$$

What is the standard enthalpy change, in kJ, for the following reaction?

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g)$$

A. –677

B. –111

C. +111

D. +677

16. Which reaction has the most negative change in entropy?

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

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

C. $PbCl_2(s) \rightarrow Pb^{2+}(aq) + 2Cl^-(aq)$

D. $C(s) + O_2(g) \rightarrow CO_2(g)$

17. What is the standard free energy change, $\Delta G^{\ominus}$, in kJ, for the following reaction?

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

Compound	$\Delta G_f^{\ominus}$ / kJ mol^{-1}
$C_2H_5OH(l)$	–175
$CO_2(g)$	–394
$H_2O(g)$	–229
$O_2(g)$	0

A. –1650

B. –1300

C. –448

D. +1300

19. Consider the endothermic reaction below.

$$5CO(g) + I_2O_5(g) \rightleftharpoons 5CO_2(g) + I_2(g)$$

According to Le Chatelier's principle, which change would result in an increase in the amount of CO_2?

A. Increasing the temperature

B. Decreasing the temperature

C. Increasing the pressure

D. Decreasing the pressure

20. Which combination of ionic radius and ionic charge would result in the highest lattice enthalpy for an ionic compound?

	Ionic radius	Ionic charge
A.	small	high
B.	large	high
C.	small	low
D.	large	low

Chem 5/Q# 102//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

15. Which types of reaction are always exothermic?

I. Neutralization

II. Decomposition

III. Combustion

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Which reaction has an enthalpy change equal to a standard enthalpy change of formation, $\Delta H_f^{\ominus}$? All reactions occur at 298 K and 1.01×10^5 Pa.

A. $C_4H_8(g)+H_2O(g)\rightarrow C_4H_9OH(l)$

B. $4CO_2(g)+5H_2O(g)\rightarrow C_4H_9OH(l)+\frac{13}{2}O_2(g)$

C. $4C(s)+5H_2(g)+\frac{1}{2}O_2(g)\rightarrow C_4H_9OH(l)$

D. $8C(s)+10H_2(g)+O_2(g)\rightarrow 2C_4H_9OH(l)$

17. Which process has an enthalpy change that represents the lattice enthalpy of sodium chloride?

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

B. $NaCl(s)\rightarrow Na(s)+\frac{1}{2}Cl_2(g)$

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

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

18. Which is the correct order of increasing magnitude of lattice enthalpy (lowest first)?

A. NaCl < KCl < MgS < MgO

B. MgO < MgS < KCl < NaCl

C. KCl < NaCl < MgS < MgO

D. MgO < NaCl < KCl < MgS

16. Which reaction has an enthalpy change equal to a standard enthalpy change of formation, $\Delta H_f^{\ominus}$? All reactions occur at 298 K and 1.01×10^5 Pa.

A. $C_4H_8(g) + H_2O(g) \rightarrow C_4H_9OH(l)$

B. $4CO_2(g) + 5H_2O(g) \rightarrow C_4H_9OH(l) + \frac{13}{2}O_2(g)$

C. $4C(s) + 5H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_4H_9OH(l)$

D. $8C(s) + 10H_2(g) + O_2(g) \rightarrow 2C_4H_9OH(l)$

17. Which process has an enthalpy change that represents the lattice enthalpy of sodium chloride?

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

B. $NaCl(s) \rightarrow Na(s) + \frac{1}{2}Cl_2(g)$

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

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

18. Which is the correct order of increasing magnitude of lattice enthalpy (lowest first)?

A. NaCl < KCl < MgS < MgO

B. MgO < MgS < KCl < NaCl

C. KCl < NaCl < MgS < MgO

D. MgO < NaCl < KCl < MgS

15. In a reaction that occurs in 50 g of aqueous solution, the temperature of the reaction mixture increases by 20 °C. If 0.10 mol of the limiting reagent is consumed, what is the enthalpy change (in kJ mol^{-1}) for the reaction? Assume the specific heat capacity of the solution = 4.2 kJ kg^{-1} K^{-1}.

A. $-0.10 \times 50 \times 4.2 \times 20$

B. $-0.10 \times 0.050 \times 4.2 \times 20$

C. $\dfrac{-50 \times 4.2 \times 20}{0.10}$

D. $\dfrac{-0.050 \times 4.2 \times 20}{0.10}$

16. Use the average bond enthalpies below to calculate the enthalpy change, in kJ, for the following reaction.

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

Bond	Bond energy / kJ mol^{-1}
H–H	440
I–I	150
H–I	300

A. +290

B. +10

C. –10

D. –290

17. Which ionic compound has the most endothermic lattice enthalpy?

A. NaCl

B. KCl

C. NaF

D. KF

18. Which change leads to an increase in entropy?

A. $CO_2(g) \rightarrow CO_2(s)$

B. $SF_6(g) \rightarrow SF_6(l)$

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

D. $NaCl(s) \rightarrow NaCl(aq)$

Chem 5/Q# 104//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

16. What is the energy, in kJ, released when 1.00 mol of carbon monoxide is burned according to the following equation?

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g) \qquad \Delta H^{\ominus} = -564 \text{ kJ}$$

A. 141

B. 282

C. 564

D. 1128

17. The specific heat of iron is 0.450 J g^{-1} K^{-1}. What is the energy, in J, needed to increase the temperature of 50.0 g of iron by 20.0 K?

A. 9.00

B. 22.5

C. 45.0

D. 450

18. What is the standard entropy change, $\Delta S^{\ominus}$, for the following reaction?

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

	$CO(g)$	$O_2(g)$	$CO_2(g)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	198	205	214

A. −189

B. −173

C. +173

D. +189

19. Which step(s) is/are endothermic in the Born-Haber cycle for the formation of LiCl?

A. $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ **and** $Li(s) \rightarrow Li(g)$

B. $Cl(g) + e^- \rightarrow Cl^-(g)$ **and** $Li(g) \rightarrow Li^+(g) + e^-$

C. $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

D. $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ **and** $Cl(g) + e^- \rightarrow Cl^-(g)$

Chem 5/Q# 105//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

14. 1.0 g of sodium hydroxide, NaOH, was added to 99.0 g of water. The temperature of the solution increased from 18.0 °C to 20.5 °C. The specific heat capacity of the solution is 4.18 $J\,g^{-1}\,K^{-1}$. Which expression gives the heat evolved in $kJ\,mol^{-1}$?

A. $\frac{2.5\times100.0\times4.18\times1000}{40.0}$

B. $\frac{2.5\times100.0\times4.18}{1000\times40.0}$

C. $\frac{2.5\times100.0\times4.18\times40.0}{1000}$

D. $\frac{2.5\times1.0\times4.18\times40.0}{1000}$

15. Which process represents the C–Cl bond enthalpy in tetrachloromethane?

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

B. $CCl_4(g) \rightarrow CCl_3(g) + Cl(g)$

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

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

16. Which reaction has the greatest increase in entropy?

A. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

B. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

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

D. $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

17. The reaction between but-1-ene and water vapour produces butan-1-ol.

$$C_4H_8(g) + H_2O(g) \rightarrow C_4H_9OH(l)$$

The standard entropy values ($S^{\ominus}$) for but-1-ene, water vapour and butan-1-ol are 310, 189 and 228 J K^{-1} mol^{-1} respectively. What is the standard entropy change for this reaction in J K^{-1} mol^{-1}?

A. −271

B. +271

C. −107

D. +107

18. A reaction has a standard enthalpy change, $\Delta H^{\ominus}$, of +10.00 kJ mol^{-1} at 298 K. The standard entropy change, $\Delta S^{\ominus}$, for the same reaction is +10.00 J K^{-1} mol^{-1}. What is the value of $\Delta G^{\ominus}$ for the reaction in kJ mol^{-1}?

A. +9.75

B. +7.02

C. −240

D. −2970

16. 75 cm^3 of an unknown gas has a mass of 0.18 g at a temperature of 25 °C and a pressure of 1 atm. Which is the correct expression for the molar mass, M, in g mol^{-1} of the gas? ($R = 8.3\ J\ K^{-1}\ mol^{-1}$, $1\ atm = 1.01 \times 10^5\ Pa$)

A. $M = \frac{0.18 \times 8.3 \times 25}{1 \times 75}$

B. $M = \frac{75 \times 10^{-6} \times 8.3 \times 25}{1.01 \times 10^5 \times 298}$

C. $M = \frac{0.18 \times 8.3 \times 298}{1.01 \times 10^5 \times 75 \times 10^{-6}}$

D. $M = \frac{1.01 \times 10^5 \times 75 \times 10^{-6}}{0.18 \times 8.3 \times 298}$

17. The average bond enthalpy for the C–H bond is 412 kJ mol^{-1}. Which process has an enthalpy change closest to this value?

A. $CH_4(g) \rightarrow C(s) + 2H_2(g)$

B. $CH_4(g) \rightarrow C(g) + 2H_2(g)$

C. $CH_4(g) \rightarrow C(g) + 4H(g)$

D. $CH_4(g) \rightarrow CH_3(g) + H(g)$

18. A reaction has a positive $\Delta H^{\ominus}$ and a negative $\Delta S^{\ominus}$ value. Which statement about this reaction is correct?

A. It is not spontaneous at any temperature.

B. It is spontaneous at all temperatures.

C. It is spontaneous only at low temperatures.

D. It is spontaneous only at high temperatures.

19. When 50 cm^3 of 1.0 $mol\,dm^{-3}$ nitric acid solution, $HNO_3(aq)$, is added to 50 cm^3 of 1.0 $mol\,dm^{-3}$ potassium hydroxide solution, $KOH(aq)$, the temperature of the mixture increases by 6.4 °C. What will be the temperature change when 25 cm^3 of each of these solutions are mixed together?

A. 1.6 °C

B. 3.2 °C

C. 6.4 °C

D. 12.8 °C

20. Which features of a positive ion lead to a higher lattice enthalpy in its compounds?

I. A higher charge on the ion

II. A smaller ionic radius

III. A lower first ionization energy of the metal to form the ion

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

21. This reaction was used in flash photography:

$$3Mg(s) + KClO_3(s) \rightarrow 3MgO(s) + KCl(s)$$

Relevant enthalpy changes of formation values are shown below.

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$KClO_3(s)$	−391
$MgO(s)$	−602
$KCl(s)$	−437

What is the enthalpy change, in kJ, of this reaction?

A. −1852

B. −648

C. +740

D. +1760

16. A gas sample occupies a volume V_1 at a pressure P_1 and a Kelvin temperature T_1. What would be the temperature of the gas, T_2, if both its pressure and volume are doubled?

A. $T_2 = \frac{1}{2}T_1$

B. $T_2 = T_1$

C. $T_2 = 2T_1$

D. $T_2 = 4T_1$

17. A possible method of preparing hydrogen peroxide is:

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \quad \Delta H^{\ominus} = x$$

$$H_2O(l) + \tfrac{1}{2}O_2(g) \rightarrow H_2O_2(l) \quad \Delta H^{\ominus} = y$$

Which expression can be used to calculate the enthalpy change for the decomposition of hydrogen peroxide using this data?

$$H_2O_2(l) \rightarrow H_2(g) + O_2(g)$$

A. $-x - y$

B. $x + y$

C. $-x + y$

D. $x - y$

18. Which of the following is correct about the energy changes during bond breaking and bond formation?

	Bond breaking	Bond formation
A.	exothermic	endothermic
B.	exothermic	exothermic
C.	endothermic	endothermic
D.	endothermic	exothermic

19. What should be the signs of ΔG, ΔH and ΔS for a chemical reaction to be spontaneous at any temperature?

	ΔG	ΔH	ΔS
A.	positive	negative	positive
B.	negative	negative	negative
C.	negative	negative	positive
D.	negative	positive	negative

20. Which compound has the highest lattice enthalpy?

A. CaO

B. CaS

C. LiF

D. LiI

21. The standard free energy changes of formation of some compounds are shown in the table:

Compound	MgO(s)	$H_2O(l)$	$Mg(OH)_2(s)$
$\Delta G^{\ominus}_f$ / kJ mol^{-1}	− 570	− 237	− 834

Which statement is correct about the following reaction?

$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$$

A. The reaction is spontaneous and $\Delta G^{\ominus} = +27$ kJ mol^{-1}.

B. The reaction is not spontaneous and $\Delta G^{\ominus} = +27$ kJ mol^{-1}.

C. The reaction is spontaneous and $\Delta G^{\ominus} = -27$ kJ mol^{-1}.

D. The reaction is not spontaneous and $\Delta G^{\ominus} = -27$ kJ mol^{-1}.

16. Which change does **not** lead to an increase in entropy?

A. Mixing nitrogen and oxygen gases at room temperature

B. Cooling steam so that it condenses to water

C. Heating hexane to its boiling point

D. Dissolving sugar in water

17. The enthalpy changes for two reactions are shown below.

$$S(s)+O_2(g)\rightarrow SO_2(g) \qquad \Delta H^{\ominus}=-300\ \text{kJ}$$
$$2S(s)+3O_2(g)\rightarrow 2SO_3(g) \qquad \Delta H^{\ominus}=-800\ \text{kJ}$$

What is the enthalpy change for this reaction in kJ?

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

A. −200

B. −500

C. −1100

D. −1400

18. Which process is exothermic?

A. $Na(s)\rightarrow Na(g)$

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

C. $Br(g)+e^{-}\rightarrow Br^{-}(g)$

D. $I_2(g)\rightarrow 2I(g)$

19. Which equation represents the standard enthalpy of formation of calcium fluoride?

A. $Ca(g)+F_2(g)\rightarrow CaF_2(g)$

B. $Ca(s)+F_2(g)\rightarrow CaF_2(s)$

C. $Ca^{2+}(g)+2F^{-}(g)\rightarrow CaF_2(s)$

D. $Ca^{2+}(s)+2F^{-}(g)\rightarrow CaF_2(s)$

20. 25 cm^3 of 1.0 mol dm^{-3} NaOH is added to 25 cm^3 of 1.0 mol dm^{-3} HCl. The temperature rise is 6°C. Which reactants will also give a temperature rise of 6°C?

A. 25 cm^3 of 2.0 mol dm^{-3} NaOH and 25 cm^3 of 2.0 mol dm^{-3} HCl.

B. 50 cm^3 of 1.0 mol dm^{-3} NaOH and 50 cm^3 of 1.0 mol dm^{-3} HCl.

C. 50 cm^3 of 0.5 mol dm^{-3} NaOH and 50 cm^3 of 0.5 mol dm^{-3} HCl.

D. 100 cm^3 of 0.25 mol dm^{-3} NaOH and 100 cm^3 of 0.25 mol dm^{-3} HCl.

21. Which reaction is the most exothermic?

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

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

C. $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(s)$

D. $Ca^{2+}(g) + S^{2-}(g) \rightarrow CaS(s)$

Chem 6/Q# 109//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

19. Consider the following reaction between hydrogen peroxide, hydrogen ions and iodide ions.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

Which changes could be used to investigate the rate of this reaction?

I. Electrical conductivity

II. Mass of solution

III. Colour intensity

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

20. Consider the following reaction between nitrogen monoxide and oxygen.

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

The reaction occurs in two steps:

Step 1:	$NO(g) + NO(g) \rightleftharpoons N_2O_2(g)$	*fast*
Step 2:	$N_2O_2(g) + O_2(g) \rightarrow 2NO_2(g)$	*slow*

What is the rate expression for this reaction?

A. Rate = $k[NO]^2$

B. Rate = $k[NO][O_2]$

C. Rate = $k[NO]^2[O_2]$

D. Rate = $k[NO][O_2]^2$

21. What happens to the rate constant, k, and the activation energy, E_a, as the temperature of a chemical reaction is increased?

	Value of k	Value of E_a
A.	increases	increases
B.	unchanged	increases
C.	decreases	unchanged
D.	increases	unchanged

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20. Which is **not** affected by an increase in temperature?

A. Rate of reaction

B. Collision frequency

C. Collision geometry

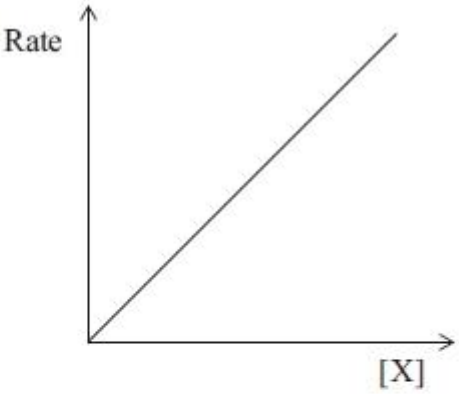
D. % of molecules with $E \geq E_a$

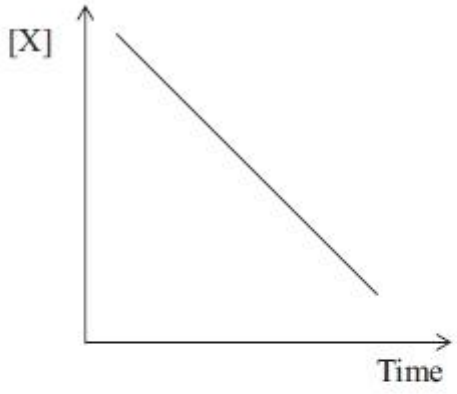
21. Which combination shows a second-order rate expression with the correct rate constant units?

	Rate expression	k units
A.	rate $= k[NH_3][BF_3]$	$mol\,dm^{-3}\,s^{-1}$
B.	rate $= k[N_2O_5]$	s^{-1}
C.	rate $= k[N_2O_5]$	$dm^3\,mol^{-1}\,s^{-1}$
D.	rate $= k[CH_3COCH_3][H^+][I_2]^0$	$dm^3\,mol^{-1}\,s^{-1}$

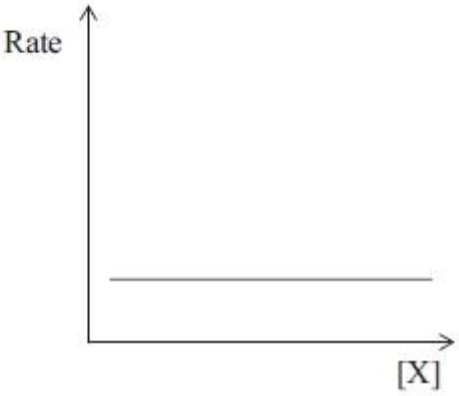
22. Which pair of graphs shows a decomposition reaction of X that obeys first-order kinetics?

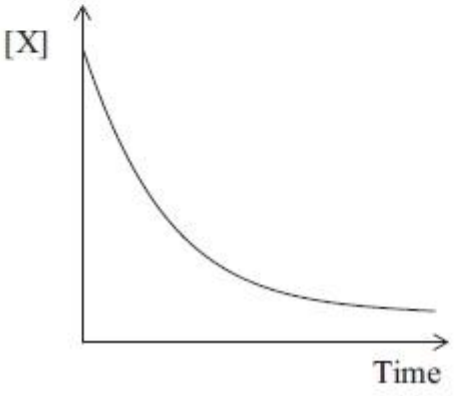
A.



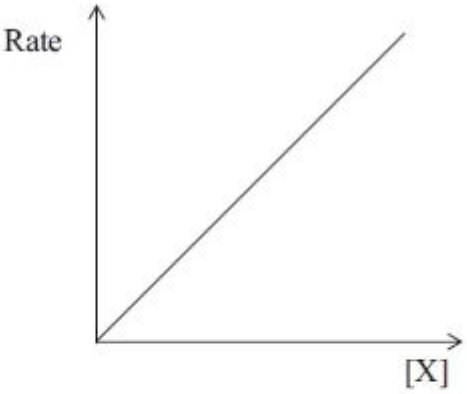


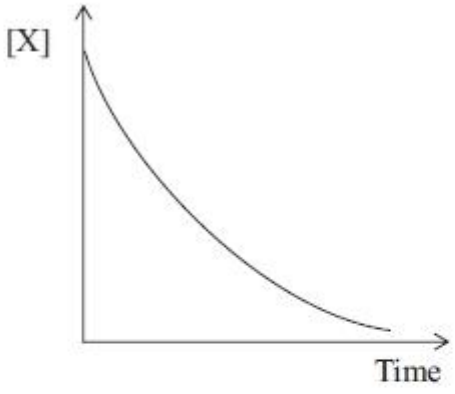
B.



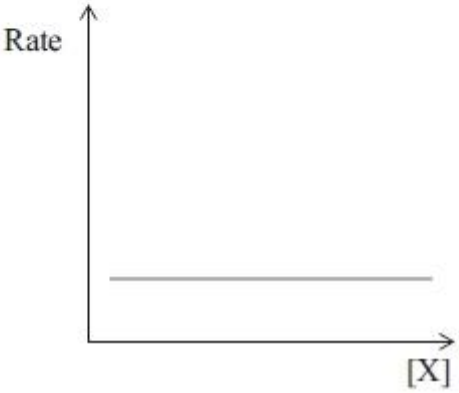


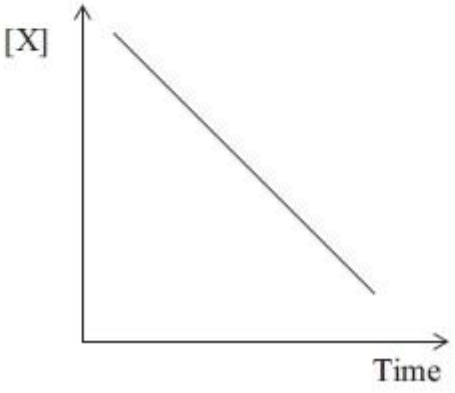
C.



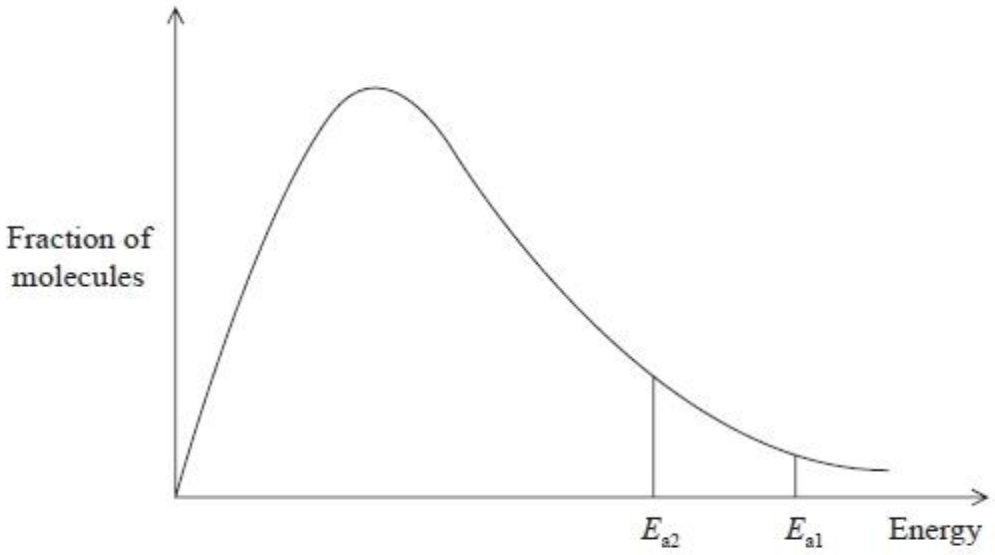


D.





19. The diagram represents the Maxwell–Boltzmann energy distribution curve of the reactants for a chemical reaction with different activation energies, E_{a1} and E_{a2}.



What is the reason why the rate of the reaction with activation energy E_{a2} is greater?

A. More frequent collisions between the particles occur.

B. More energetic collisions between the particles occur.

C. A catalyst has been added.

D. The temperature is higher.

20. X and Y react according to the equation $2X + Y \rightarrow Z$. The reaction can be described by the following mechanism:

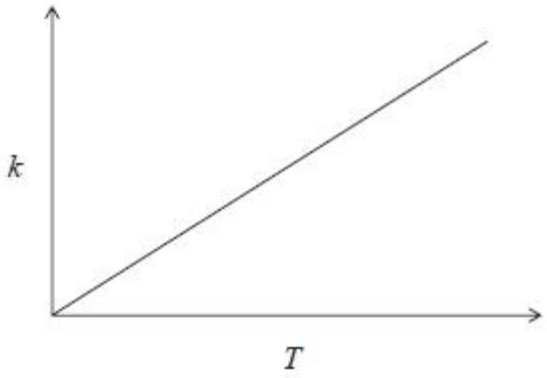
$$X + X \rightarrow X_2 \quad \textit{slow}$$
$$X_2 + Y \rightarrow Z \quad \textit{fast}$$

What is the order of the reaction with respect to **X** and **Y**?

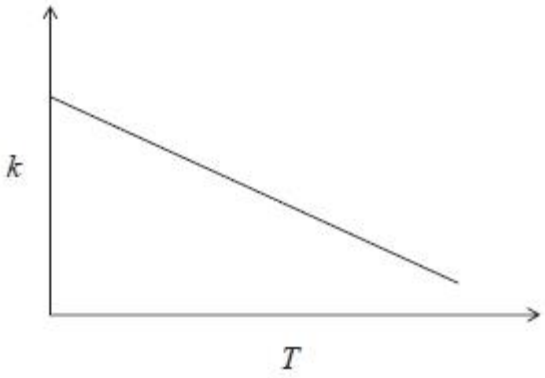
	X	Y
A.	First	Zero
B.	First	First
C.	Second	Zero
D.	Second	First

21. The rate constant for a reaction is determined at different temperatures. Which diagram represents the relationship between the rate constant, k, and temperature, T, in K?

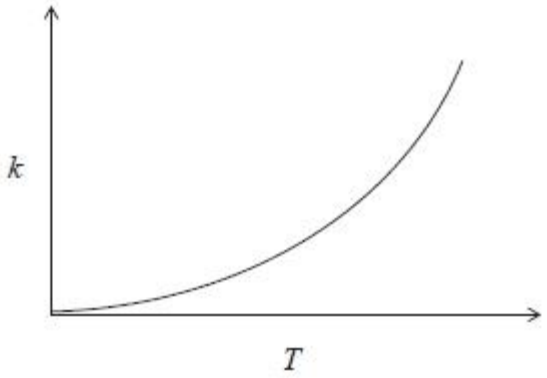
A.



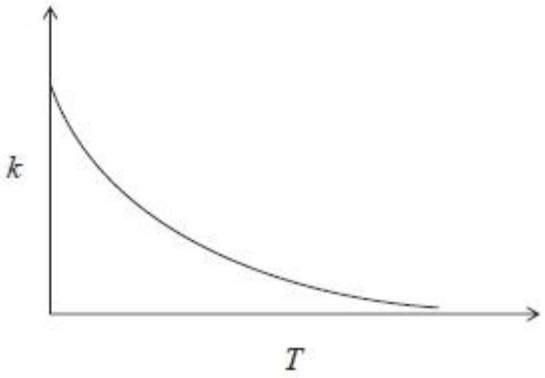
B.



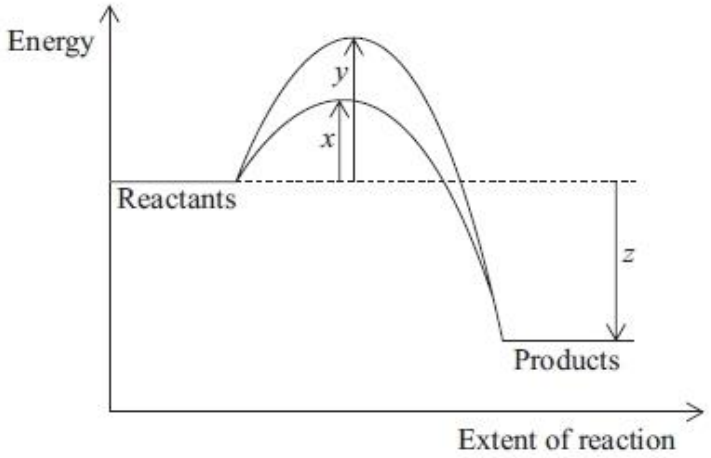
C.



D.



20. The diagram below shows the energy changes for a reaction with and without a catalyst. Which symbols represent the activation energy, E_a, and the enthalpy change, ΔH, for the reaction with a catalyst?



	E_a (with a catalyst)	ΔH
A.	x	z
B.	y	z
C.	z	x
D.	$y - x$	z

21. The following experimental rate data were obtained for a reaction carried out at temperature T.

$$A(g) + B(g) \rightarrow C(g) + D(g)$$

Initial [A(g)] / mol dm^{-3}	Initial [B(g)] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
3.00×10^{-1}	2.00×10^{-1}	1.89×10^{-2}
3.00×10^{-1}	4.00×10^{-1}	1.89×10^{-2}
6.00×10^{-1}	4.00×10^{-1}	7.56×10^{-2}

What are the orders with respect to A(g) and B(g)?

	Order with respect to A(g)	Order with respect to B(g)
A.	zero	second
B.	first	zero
C.	second	zero
D.	second	first

22. Consider the following proposed two-step reaction mechanism at temperature T.

Step 1: $2NO_2(g) \xrightarrow{k_1} NO(g) + NO_3(g)$ *Slow*

Step 2: $NO_3(g) + CO(g) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ *Fast*

Which statements are correct?

I. The overall reaction is $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$.

II. Step 1 is the rate-determining step of the reaction.

III. The rate expression for Step 1 is rate $= k_1[NO_2]^2$.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

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19. Which statements explain the increase in the rate of a reaction when the temperature is increased?

I. More particles have energy greater than the activation energy.

II. The frequency of collisions increases.

III. The activation energy decreases.

A. I and II only

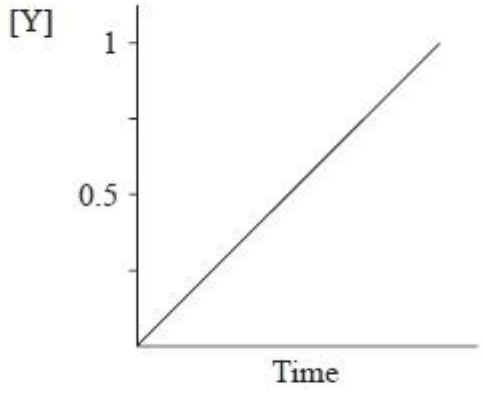
B. I and III only

C. II and III only

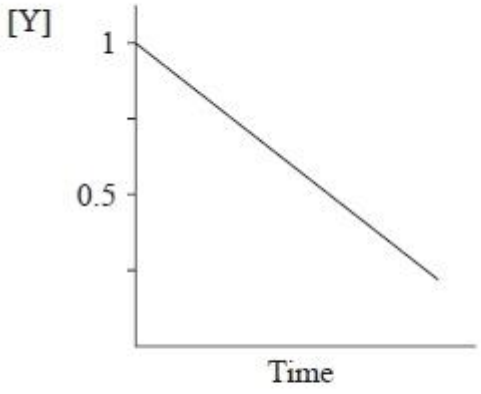
D. I, II and III

20. Experimental data shows that a reaction in which Y is a reactant is first order with respect to Y. Which graph shows this first-order relationship?

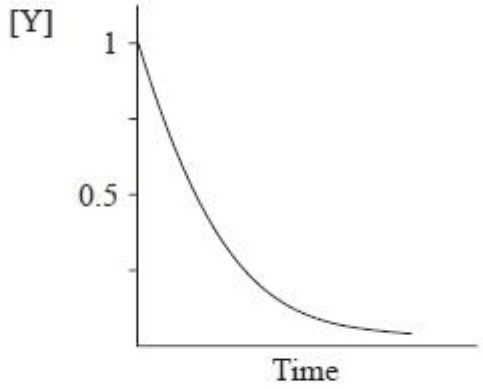
A.



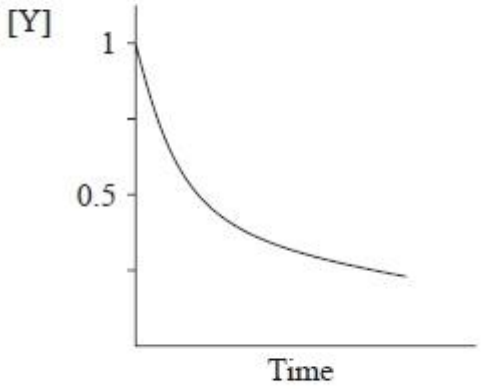
B.



C.



D.



21. Which statement about a reaction best describes the relationship between the temperature, T, and the rate constant, k?

A. As T increases, k decreases linearly.

B. As T increases, k decreases non-linearly.

C. As T increases, k increases linearly.

D. As T increases, k increases non-linearly.

22. Carbon monoxide and nitrogen dioxide react to form carbon dioxide and nitrogen monoxide according to the following equation.

$$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$$

The reaction occurs in a series of steps. The equation for the rate-determining step is given below.

$$2NO_2(g) \rightarrow NO_3(g) + NO(g)$$

What is the rate expression for this reaction?

A. $\text{rate} = k[CO(g)][NO_2(g)]$

B. $\text{rate} = k[NO_2(g)]^2$

C. $\text{rate} = k[NO_3(g)][NO(g)]$

D. $\text{rate} = k[CO_2(g)][NO(g)]$

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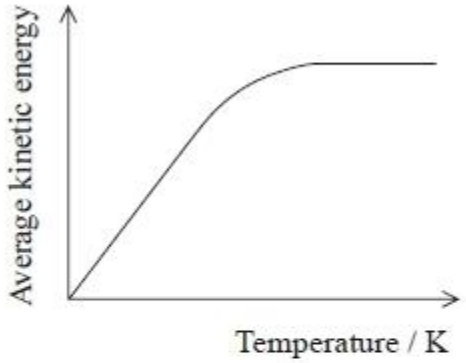
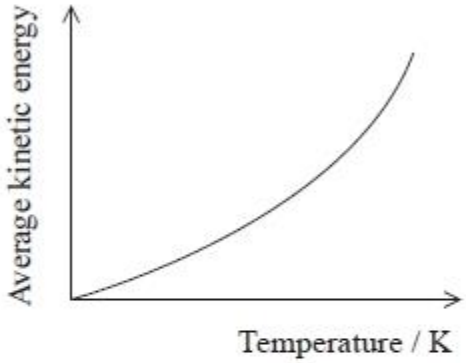
19. Which graph best represents the relationship between the average kinetic energy of molecules of a gas and temperature in K?

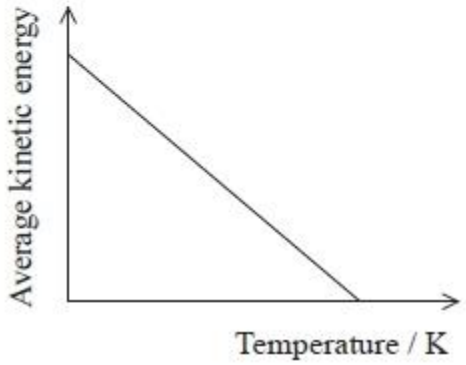
A.



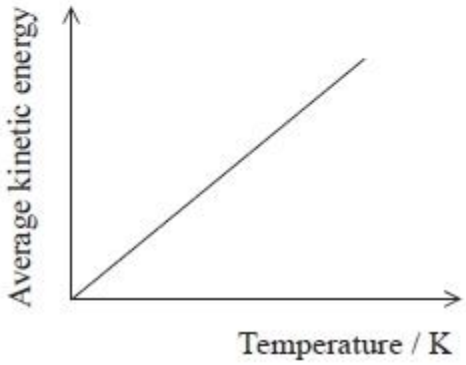
B.



C.



D.



20. For the gas phase reaction:

$$A(g) + B(g) \rightarrow C(g)$$

the experimentally determined rate expression is: rate = k [A] [B]^2

By what factor will the rate change if the concentration of A is tripled and the concentration of B is halved?

A. 0.75

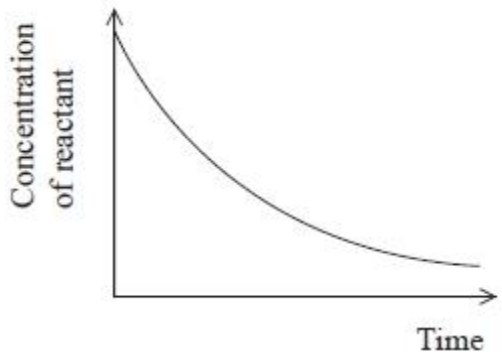
B. 1.5

C. 6

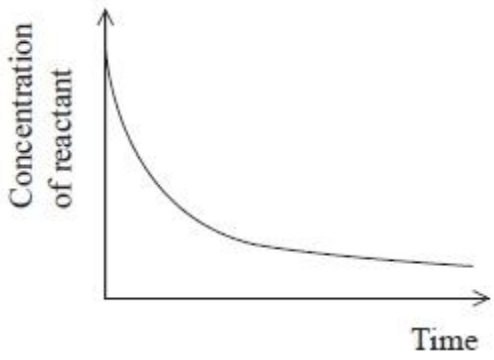
D. 12

21. Which graph best represents a second-order reaction?

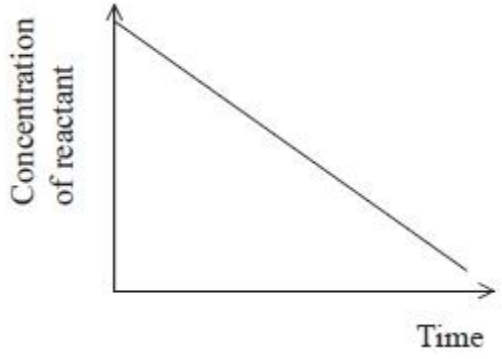
A.



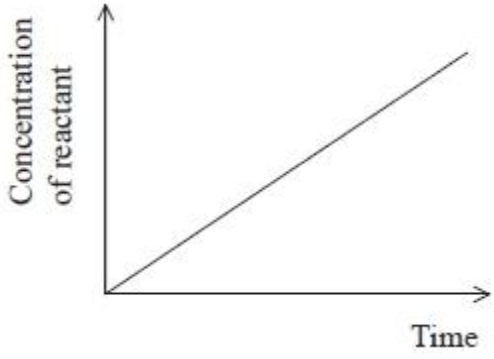
B.



C.



D.



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19. Which piece of equipment could **not** be used in an experiment to measure the rate of this reaction?

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

A. A colorimeter

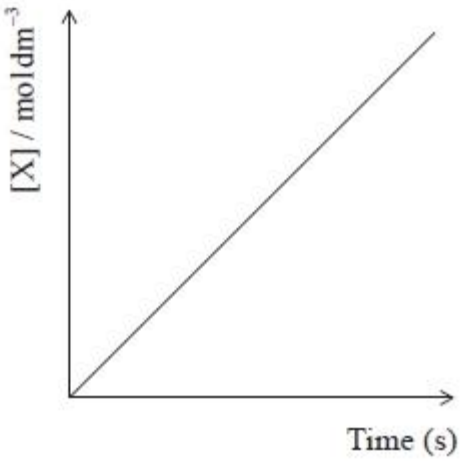
B. A gas syringe

C. A stopwatch

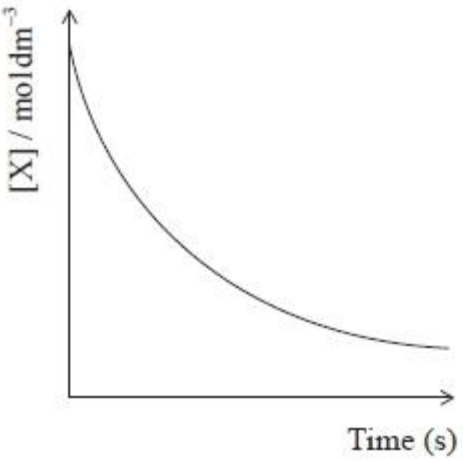
D. A pH meter

20. Which graph would be produced by a 2nd order reaction if the rate equation is rate $= k[X]^2$?

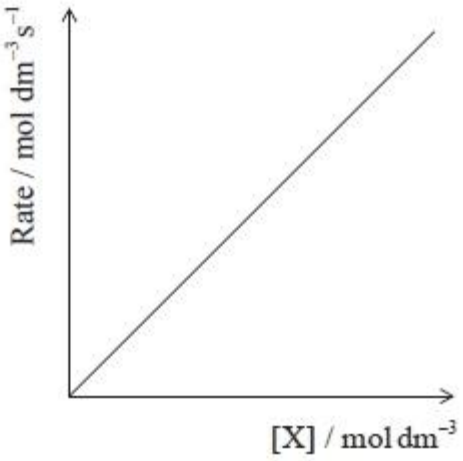
A.



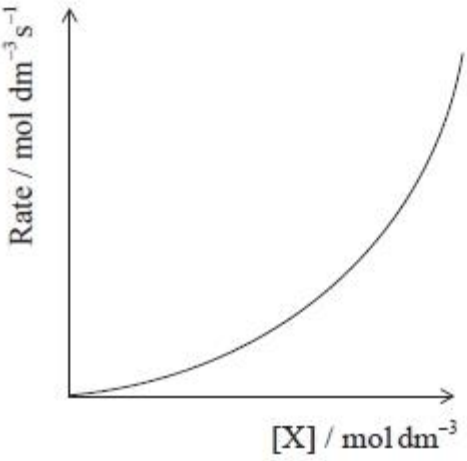
B.



C.



D.



21. Which step in a multi-step reaction mechanism will be rate-determining?

A. The first step

B. The last step

C. The step with the highest activation energy

D. The step with the lowest activation energy

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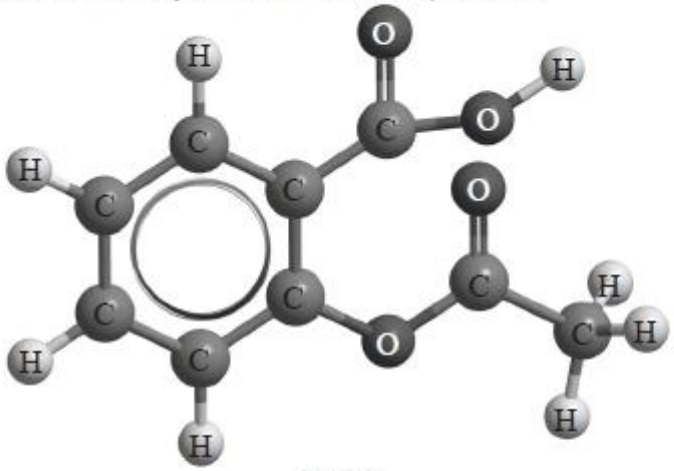
15. Which reactions are exothermic?

I. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

II. Reaction of aspirin with sodium hydroxide



Aspirin

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

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 electron affinity of chlorine?

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

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

C. $Cl_2(g) + 2e^- \rightarrow 2Cl^-(g)$

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

17. During which process is there a **decrease** in the entropy of the system?

A. $Ag(s) + 2H^+(aq) + NO_3^-(aq) \rightarrow Ag^+(aq) + H_2O(l) + NO_2(g)$

B. $Ba(OH)_2(s) \rightarrow BaO(s) + H_2O(g)$

C. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$

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

18. Which are appropriate units for the rate of a reaction?

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

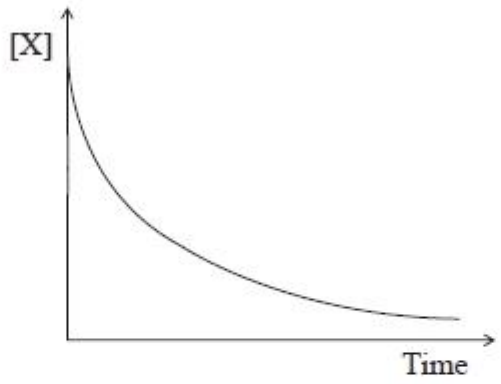
B. $mol\,dm^{-3}\,s$

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

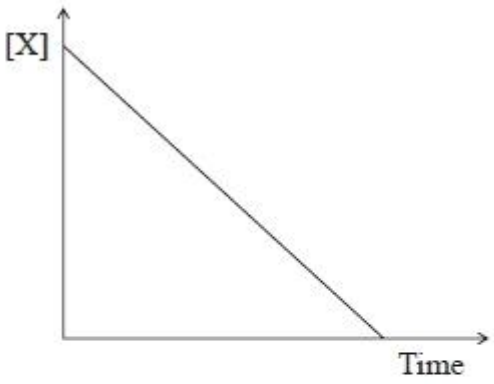
D. s

19. Which graph represents a reaction that is second order with respect to X for the reaction $X \rightarrow$ products?

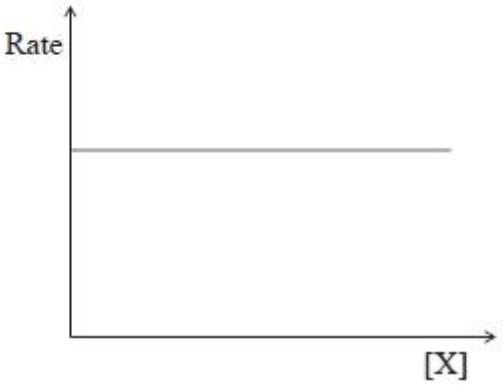
A.



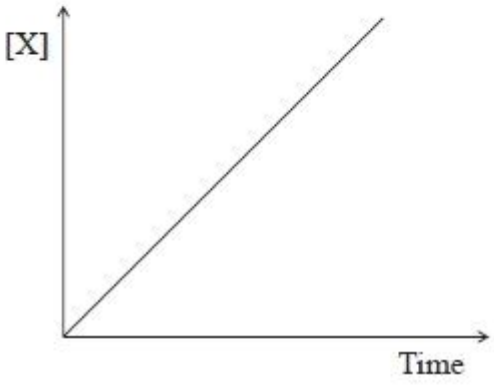
B.



C.



D.



20. Consider the reaction:

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g)$$

One suggested mechanism is:

$$NO(g) + Br_2(g) \underset{}{\overset{k_1}{\rightleftharpoons}} NOBr_2(g) \qquad \textit{fast}$$

$$NOBr_2(g) + NO(g) \xrightarrow{k_2} 2NOBr(g) \qquad \textit{slow}$$

Which statements are correct?

I. $NOBr_2(g)$ is an intermediate.

II. The second step is the rate-determining step.

III. rate $= k[NO]^2[Br_2]$

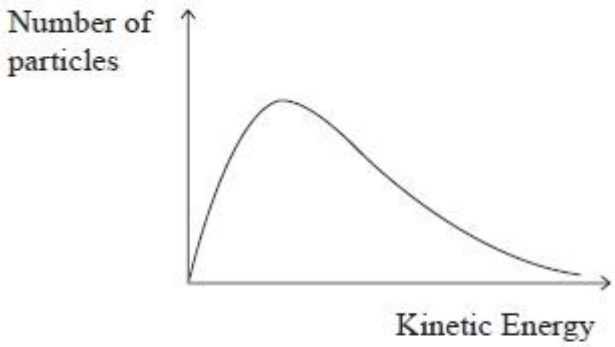
A. I and II only

B. I and III only

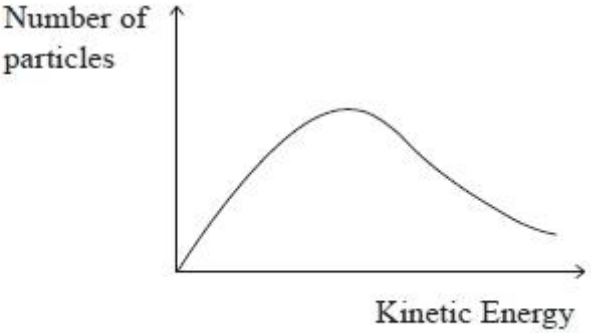
C. II and III only

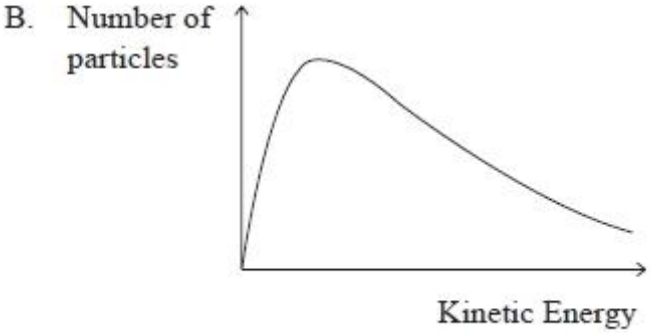
D. I, II and III

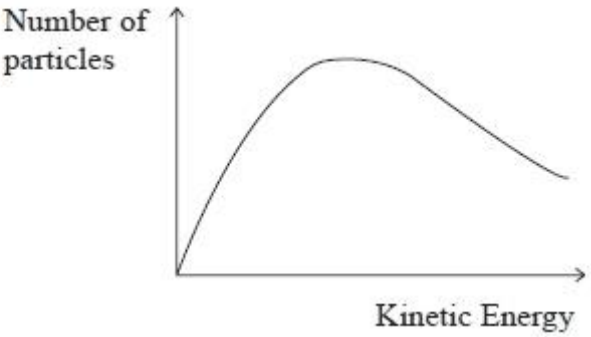
19. The Maxwell–Boltzmann curve below shows the distribution of kinetic energies for the particles in a sample of gas.

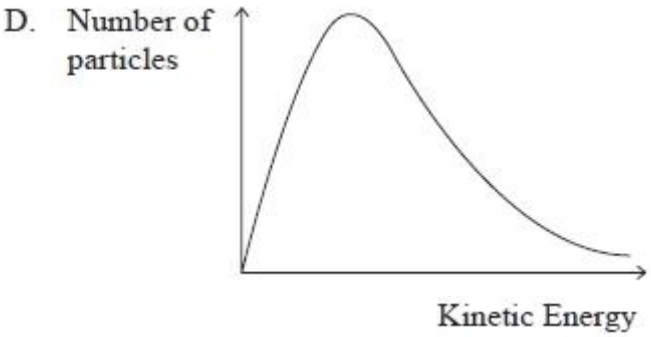


Which is the shape of the curve for the same sample of gas at a higher temperature? All graphs are drawn to the same scale.

A. 

B. 

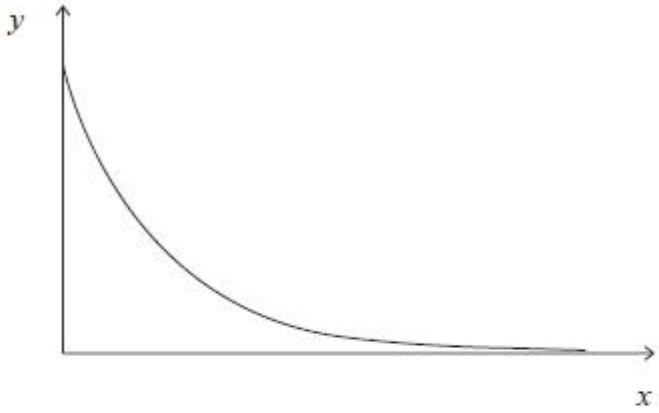
C. 

D. 

20. The decomposition of N_2O_5 occurs according to the following equation.

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

The reaction is first order with respect to N_2O_5. What combination of variables could the axes represent on the graph below?



	x-axis	*y*-axis
A.	time	$[N_2O_5]$
B.	$[N_2O_5]$	time
C.	$[N_2O_5]$	rate of reaction
D.	rate of reaction	$[N_2O_5]$

21. What is the effect of an increase in temperature on the rate constant of the forward reaction, k, and on the equilibrium constant, K_c, of an exothermic reversible reaction?

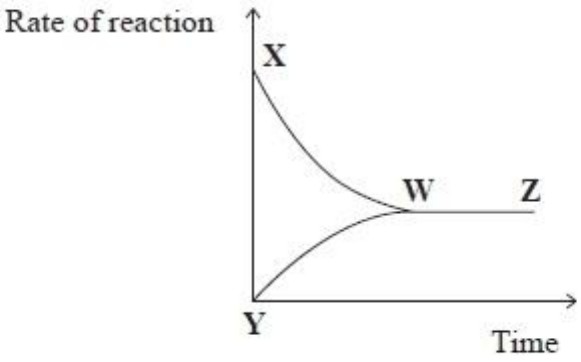
A. k decreases, K_c increases

B. k increases, K_c decreases

C. k decreases, K_c decreases

D. k increases, K_c increases

22. The graph represents the rates of the forward and backward reactions of a reversible reaction.



Which statement is correct?

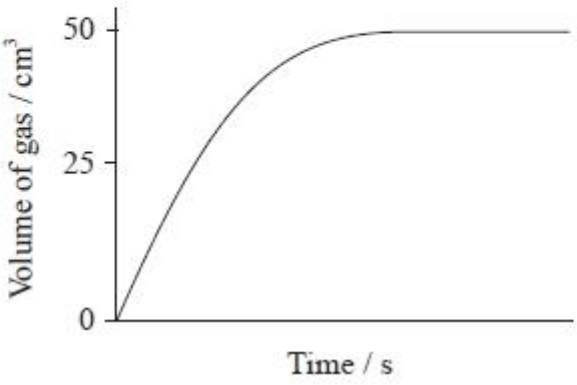
A. **XWZ** represents the rate of the forward reaction.

B. At **Y**, the rate of the forward and backward reactions is zero.

C. Between **W** and **Z**, the concentrations of products and reactants are equal.

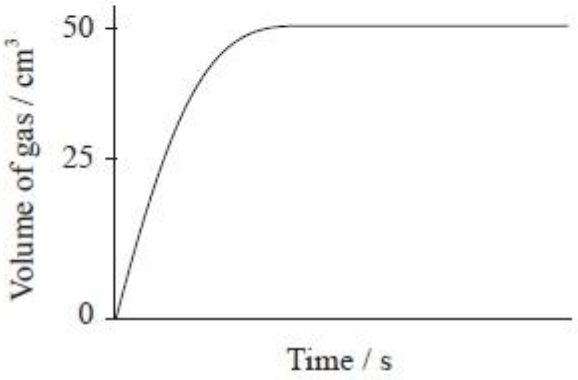
D. Between **Y** and **W**, the concentration of the reactants increases.

19. A student added 0.20 g of calcium carbonate powder to 100 cm^3 of 1.0 mol dm^{-3} hydrochloric acid (an excess) and measured the volume of the gas that was evolved. The graph of the results is shown below.

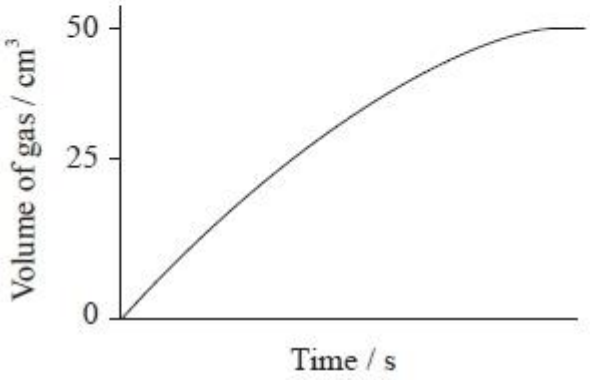


Which graph would be obtained if 0.20 g of calcium carbonate powder is added to 100 cm^3 of 0.5 mol dm^{-3} hydrochloric acid (an excess)?

A.



B.



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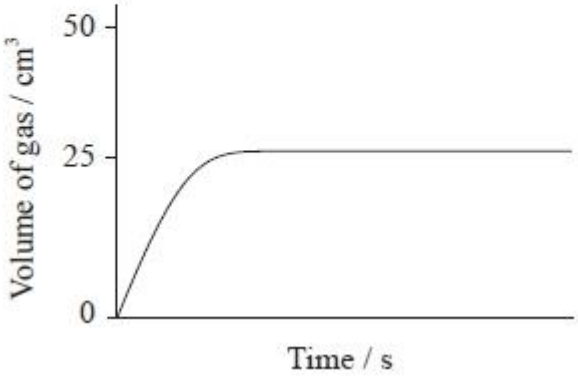
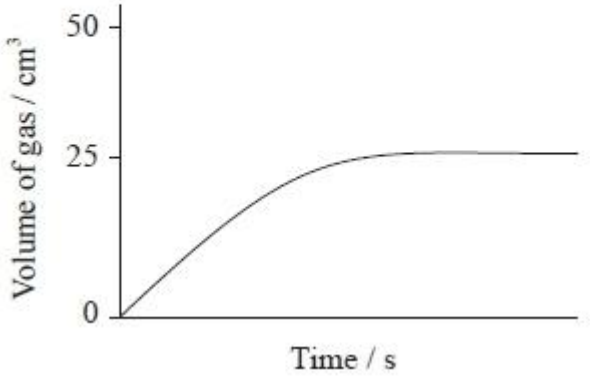


D.



20. Which statement about the kinetic theory is **not** correct?

A. The particles in ice vibrate about fixed points.

B. The particles in steam have more energy than the particles in ice.

C. All the particles in water have the same amount of energy at 298 K.

D. Evaporation of water occurs at all temperatures between 273 K and 373 K when the atmospheric pressure is 101 kPa.

21. The rate expression for the reaction between iodine and propanone with an acid catalyst is found to be:

$$\text{rate} = k[H^+]^1 [I_2]^0 [CH_3COCH_3]^1$$

What is the overall order of the reaction?

A. 0

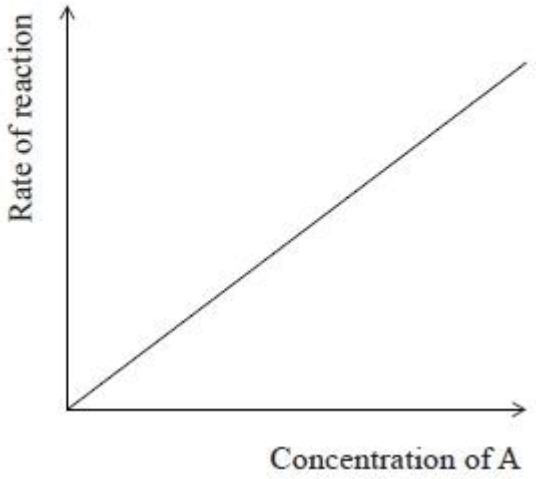
B. 1

C. 2

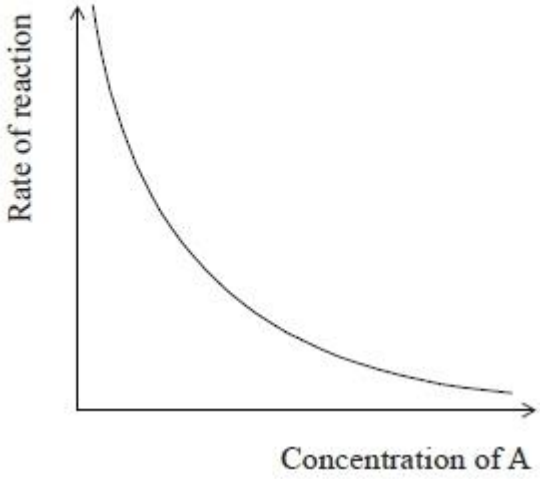
D. 3

22. Which graph represents a reaction that is first order with respect to reactant A.

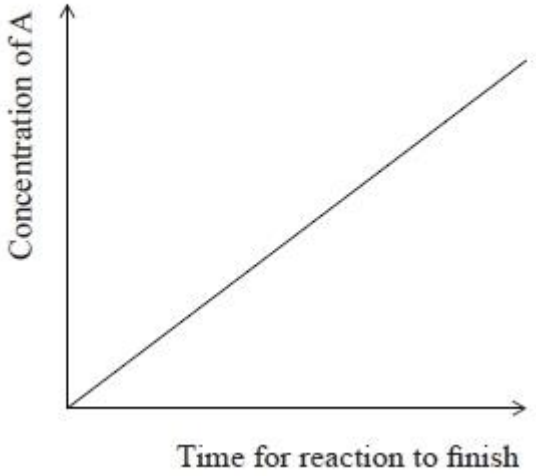
A.



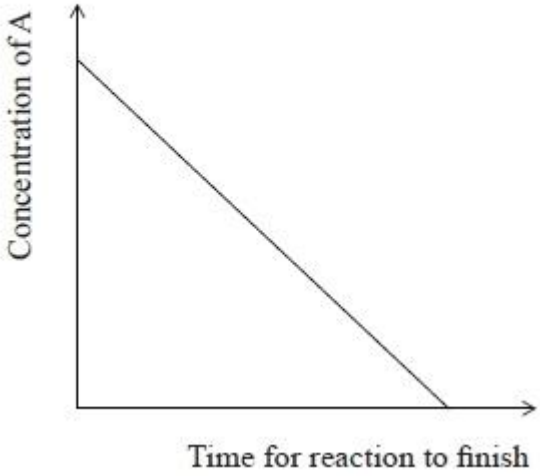
B.



C.



D.



20. Sodium carbonate and hydrochloric acid react according to the equation below.

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

Which conditions will produce the fastest initial rate with 2.0 g of powdered sodium carbonate?

A. 100 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 323 K

B. 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at 323 K

C. 100 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 348 K

D. 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at 348 K

21. The rate information below was obtained for the following reaction at a constant temperature.

$$2NO_2(g) + F_2(g) \rightarrow 2NO_2F(g)$$

$[NO_2]$ / mol dm^{-3}	$[F_2]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
2.0×10^{-3}	1.0×10^{-2}	4.0×10^{-4}
4.0×10^{-3}	1.0×10^{-2}	8.0×10^{-4}
4.0×10^{-3}	2.0×10^{-2}	1.6×10^{-3}

What are the orders of the reaction with respect to NO_2 and F_2?

A. NO_2 is first order and F_2 is second order

B. NO_2 is second order and F_2 is first order

C. NO_2 is first order and F_2 is first order

D. NO_2 is second order and F_2 is second order

22. Consider the following reaction.

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

A proposed reaction mechanism is:

$$NO(g) + NO(g) \rightleftharpoons N_2O_2(g) \quad \textit{fast}$$
$$N_2O_2(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g) \quad \textit{slow}$$
$$N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g) \quad \textit{fast}$$

What is the rate expression?

A. rate $= k[H_2][NO]^2$

B. rate $= k[N_2O_2][H_2]$

C. rate $= k[NO]^2[H_2]^2$

D. rate $= k[NO]^2[N_2O_2]^2[H_2]$

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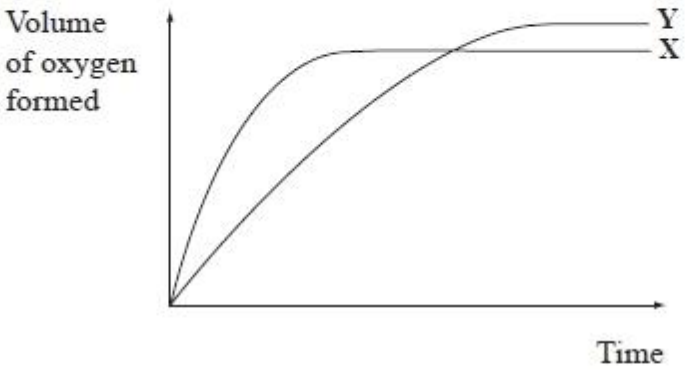
20. Curve **X** on the graph below shows the volume of oxygen formed during the catalytic decomposition of a 1.0 mol dm^{-3} solution of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$$



Which change would produce the curve **Y**?

A. Adding water

B. Adding some 0.1 mol dm^{-3} hydrogen peroxide solution

C. Using a different catalyst

D. Lowering the temperature

21. Bromine and nitrogen(II) oxide react according to the following equation.

$$Br_2(g) + 2NO(g) \rightarrow 2NOBr(g)$$

Which rate equation is consistent with the experimental data?

$[Br_2]$ / mol dm^{-3}	[NO] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
0.10	0.10	1.0×10^{-6}
0.20	0.10	4.0×10^{-6}
0.20	0.40	4.0×10^{-6}

A. rate = $k\,[Br_2]^2\,[NO]$

B. rate = $k\,[Br_2]\,[NO]^2$

C. rate = $k\,[Br_2]^2$

D. rate = $k\,[NO]^2$

22. Consider the reaction between gaseous iodine and gaseous hydrogen.

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^{\ominus} = -9 \text{ kJ}$$

Why do some collisions between iodine and hydrogen **not** result in the formation of the product?

A. The I_2 and H_2 molecules do not have sufficient energy.

B. The system is in equilibrium.

C. The temperature of the system is too high.

D. The activation energy for this reaction is very low.

23. Which step is the rate-determining step of a reaction?

A. The step with the lowest activation energy

B. The final step

C. The step with the highest activation energy

D. The first step

19. Which changes increase the rate of the reaction below?

$$C_4H_{10}(g) + Cl_2(g) \rightarrow C_4H_9Cl(l) + HCl(g)$$

I. Increase of pressure

II. Increase of temperature

III. Removal of HCl(g)

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

20. Consider the following reaction.

$$2P + Q \rightarrow R + S$$

This reaction occurs according to the following mechanism.

$$P + Q \rightarrow X \quad \textit{slow}$$
$$P + X \rightarrow R + S \quad \textit{fast}$$

What is the rate expression?

A. rate $= k[P]$

B. rate $= k[P][X]$

C. rate $= k[P][Q]$

D. rate $= k[P]^2[Q]$

21. What happens when the temperature of a reaction increases?

A. The activation energy increases.

B. The rate constant increases.

C. The enthalpy change increases.

D. The order of the reaction increases.

18. Which unit could be used for the rate of a chemical reaction?

A. mol

B. mol dm^{-3}

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

D. dm^{3}

21. The following data were obtained for the reaction between gases A and B.

Experiment	Initial [A] / mol dm^{-3}	Initial [B] / mol dm^{-3}	Initial rate / $\text{mol dm}^{-3}\text{ min}^{-1}$
1	1.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
2	2.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
3	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-4}

Which relationship represents the rate expression for the reaction?

A. $\text{rate} = k[\text{B}]^2$

B. $\text{rate} = k[\text{A}]^2$

C. $\text{rate} = k[\text{A}]$

D. $\text{rate} = k[\text{B}]$

22. Consider the following reaction.

$$\text{NO}_2(\text{g}) + \text{CO}(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{CO}_2(\text{g})$$

At $T < 227\,^{\circ}\text{C}$ the rate expression is $\text{rate} = k[\text{NO}_2]^2$. Which of the following mechanisms is consistent with this rate expression?

A. $\text{NO}_2 + \text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4$ *fast*
$\text{N}_2\text{O}_4 + 2\text{CO} \rightarrow 2\text{NO} + 2\text{CO}_2$ *slow*

B. $\text{NO}_2 + \text{CO} \rightarrow \text{NO} + \text{CO}_2$ *slow*

C. $\text{NO}_2 \rightarrow \text{NO} + \text{O}$ *slow*
$\text{CO} + \text{O} \rightarrow \text{CO}_2$ *fast*

D. $\text{NO}_2 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$ *slow*
$\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$ *fast*

19. Which experimental procedure could be used to determine the rate of reaction for the reaction between a solution of cobalt chloride, $CoCl_2(aq)$, and concentrated hydrochloric acid, $HCl(aq)$?

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

A. Measure the change in pH in a given time

B. Measure the change in mass in a given time

C. Use a colorimeter to measure the change in colour in a given time

D. Measure the change in volume of the solution in a given time

20. Powdered manganese(IV) oxide, $MnO_2(s)$, increases the rate of the decomposition reaction of hydrogen peroxide, $H_2O_2(aq)$. Which statements about MnO_2 are correct?

I. The rate is independent of the particle size of MnO_2.

II. MnO_2 provides an alternative reaction pathway for the decomposition with a lower activation energy.

III. All the MnO_2 is present after the decomposition of the hydrogen peroxide is complete.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Questions 21 and 22 refer to the following reaction.

Sodium thiosulfate solution, $Na_2S_2O_3(aq)$, and hydrochloric acid, $HCl(aq)$, react spontaneously to produce solid sulfur, $S(s)$, according to the equation below.

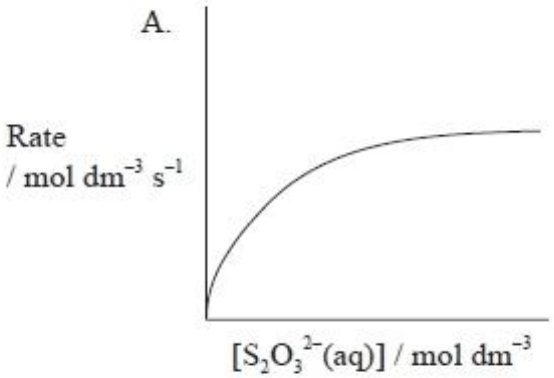
$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$

A student experimentally determined the rate expression to be:

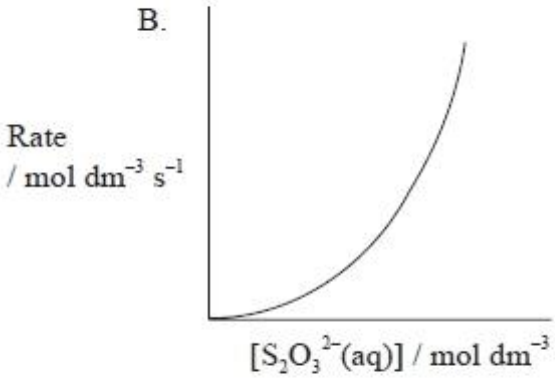
$$\text{rate} = k\,[S_2O_3^{2-}(aq)]^2$$

21. Which graph is consistent with this information?

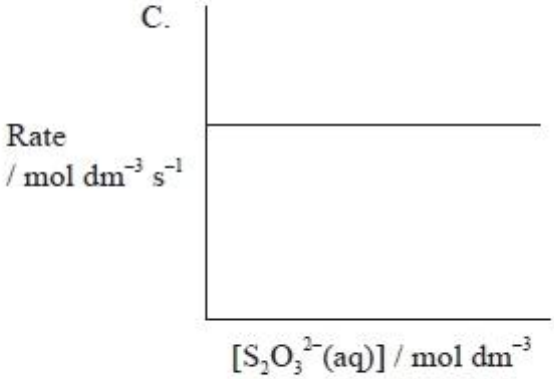
A.



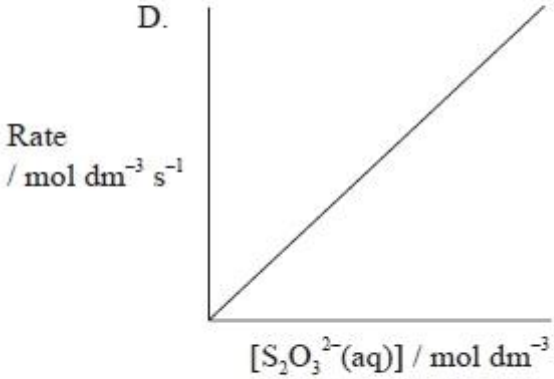
B.



C.



D.



22. Which reaction could be the rate-determining step?

A. $S_2O_3^{2-}(aq) + H^+(aq) \rightarrow S_2O_2(aq) + OH^-(aq)$

B. $S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S_2O_2(aq) + H_2O(l)$

C. $S_2O_3^{2-}(aq) \rightarrow S(s) + SO_3^{2-}(aq)$

D. $2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{4-}(aq)$

19. Hydrochloric acid is reacted with large pieces of calcium carbonate, the reaction is then repeated using calcium carbonate powder. How does this change affect the activation energy and the collision frequency?

	Activation energy	Collision frequency
A.	increases	increases
B.	stays constant	increases
C.	increases	stays constant
D.	stays constant	stays constant

20. Two species, P and Q, react together according to the following equation.

$$P + Q \rightarrow R$$

The accepted mechanism for this reaction is

$$P + P \rightleftharpoons P_2 \qquad \textit{fast}$$

$$P_2 + Q \rightarrow R + P \qquad \textit{slow}$$

What is the order with respect to P and Q?

	P	Q
A.	1	1
B.	1	2
C.	2	1
D.	2	2

21. The activation energy of a reaction may be determined by studying the effect of a particular variable on the reaction rate. Which variable must be changed?

A. pH

B. Concentration

C. Surface area

D. Temperature

20. What is the function of iron in the Haber process?

A. It shifts the position of equilibrium towards the products.

B. It decreases the rate of the reaction.

C. It provides an alternative reaction pathway with a lower activation energy.

D. It reduces the enthalpy change of the reaction.

21. Consider the following reaction.

$$5Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

The rate expression for the reaction is found to be:

$$\text{rate} = k[Br^-][BrO_3^-][H^+]^2$$

Which statement is correct?

A. The overall order is 12.

B. Doubling the concentration of all of the reactants at the same time would increase the rate of the reaction by a factor of 16.

C. The units of the rate constant, k, are $\text{mol dm}^{-3}\ \text{s}^{-1}$.

D. A change in concentration of Br^- or BrO_3^- does not affect the rate of the reaction.

22. The rate expression for a reaction is:

$$\text{rate} = k[X][Y]$$

Which statement is correct?

A. As the temperature increases the rate constant decreases.

B. The rate constant increases with increased temperature but eventually reaches a constant value.

C. As the temperature increases the rate constant increases.

D. The rate constant is not affected by a change in temperature.

23. Consider the following reaction mechanism.

Step 1	$H_2O_2 + I^- \rightarrow H_2O + IO^-$	*slow*
Step 2	$H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$	*fast*

Which statement correctly identifies the rate-determining step and the explanation?

A. Step 2 because it is the faster step

B. Step 1 because it is the slower step

C. Step 1 because it is the first step

D. Step 2 because it is the last step

24. Which statement is correct for the equilibrium $H_2O(l) \rightleftharpoons H_2O(g)$ in a closed system at 100 °C?

A. All the $H_2O(l)$ molecules have been converted to $H_2O(g)$.

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

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

D. The pressure remains constant.

25. Which are definitions of an acid according to the Brønsted-Lowry and Lewis theories?

	Brønsted-Lowry theory	Lewis theory
A.	proton donor	electron pair acceptor
B.	proton acceptor	electron pair acceptor
C.	proton acceptor	electron pair donor
D.	proton donor	electron pair donor

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19. What is the best definition of *rate of reaction*?

A. The time it takes to use up all the reactants

B. The rate at which all the reactants are used up

C. The time it takes for one of the reactants to be used up

D. The increase in concentration of a product per unit time

20. Which factors can affect reaction rate?

I. The state of the reactants

II. The frequency of the collisions between particles

III. The average kinetic energy of the particles

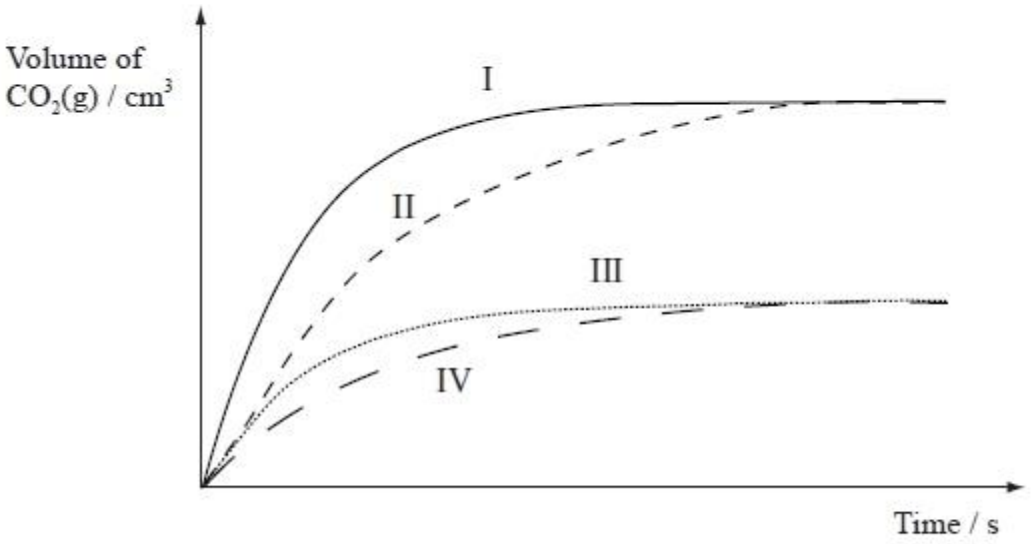
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

21. Equal masses of powdered calcium carbonate were added to separate solutions of hydrochloric acid. The calcium carbonate was in excess. The volume of carbon dioxide produced was measured at regular intervals. Which curves best represent the evolution of carbon dioxide against time for the acid solutions shown in the table below.



	25 cm^3 of 2 mol dm^{-3} HCl	50 cm^3 of 1 mol dm^{-3} HCl	25 cm^3 of 1 mol dm^{-3} HCl
A.	I	III	IV
B.	I	IV	III
C.	I	II	III
D.	II	I	III

Questions 22 and 23 refer to the following reaction.

$$X_2 + 2Y \rightarrow 2XY$$

The reaction occurs in a series of steps.

$X_2 \rightarrow 2X$ *slow*

$X + Y \rightarrow XY$ *fast*

22. What is the rate-determining step for this reaction mechanism?

A. $X_2 + 2Y \rightarrow 2XY$

B. $X_2 + Y \rightarrow XY + X$

C. $X_2 \rightarrow 2X$

D. $X + Y \rightarrow XY$

23. What is the rate expression for this reaction?

A. rate = k [XY]

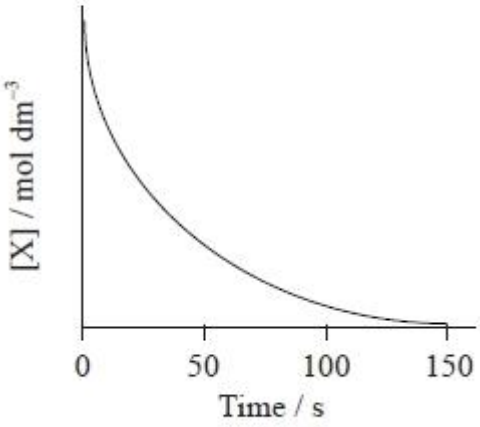
B. rate = k [X_2][Y]^2

C. rate = k [X_2]

D. rate = k [2X]

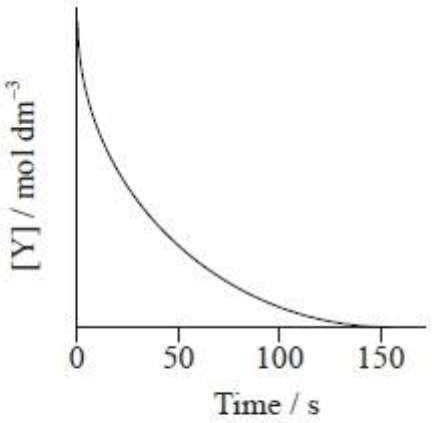
22. The graph below shows how the concentration of X changes with time during the following reaction:

$$X \rightarrow Y$$

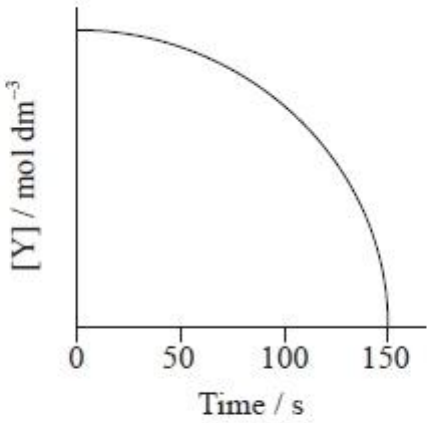


Which graph shows the change in concentration of Y during the same time period?

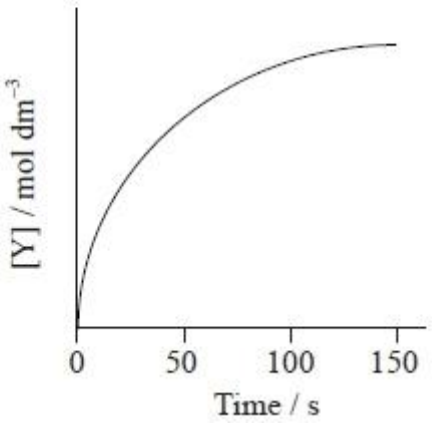
A.



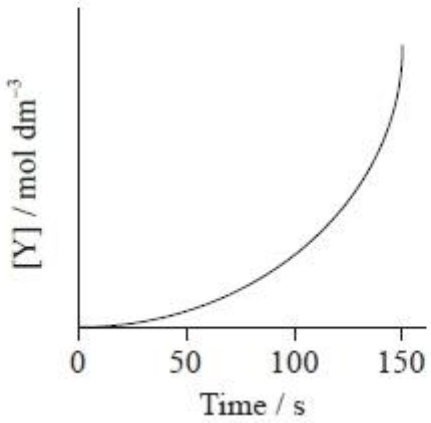
B.



C.



D.



23. The activation energy for a reaction can be determined graphically using the Arrhenius equation:

$$k = Ae^{\frac{-E_a}{RT}}$$

Which plot gives a straight line graph?

	Vertical axis	Horizontal axis
A.	k	$\frac{1}{T}$
B.	k	$\ln \frac{1}{T}$
C.	$\ln k$	$\ln \frac{1}{T}$
D.	$\ln k$	$\frac{1}{T}$

24. Nitrogen dioxide can react with carbon monoxide in the exhaust gases of car engines:

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

The following mechanism has been proposed:

$$NO_2(g) + NO_2(g) \rightarrow N_2O_4(g) \qquad \textit{slow}$$

$$N_2O_4(g) + CO(g) \rightarrow NO_2(g) + CO_2(g) + NO(g) \qquad \textit{fast}$$

What is the rate equation for this mechanism?

A. Rate $= k\,[NO_2(g)]\,[CO(g)]$

B. Rate $= k\,[NO_2(g)]^2$

C. Rate $= k\,[N_2O_4(g)]\,[CO(g)]$

D. Rate $= k\,[NO_2(g)]^2\,[CO(g)]$

22. Which statement explains why increasing the temperature increases the rate of a chemical reaction?

A. More molecules have energy equal to or greater than the activation energy.

B. At a higher temperature the activation energy for the reaction is lower.

C. More molecules have the correct collision geometry.

D. The reaction proceeds according to Le Chatelier's principle.

23. Which statement is correct about the overall order of a chemical reaction?

A. It can be deduced from the stoichiometric coefficients of the equation.

B. It can only be determined experimentally.

C. It is always affected when the concentrations of the reactants are increased.

D. It is always the same as the molecularity.

24. The rate expression for the decomposition of X is

$$\text{rate} = k\,[\text{X}]$$

Values of half-life were measured at intervals during the decomposition.
Which of the following shows the correct **intervals** for the successive half lives (in minutes)?

A. 0.2, 0.4, 0.6, 0.8

B. 0.4, 0.4, 0.4, 0.4

C. 0.8, 0.6, 0.4, 0.2

D. 0.8, 0.4, 0.2, 0.1

25. Consider the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\,\text{kJ}$$

Which of the following affects the value of K_c ?

A. Adding a catalyst

B. Increasing the pressure

C. Increasing the concentrations of nitrogen and hydrogen

D. Increasing the temperature

22. The table shows data for a reaction between X and Y.

Experiment	[X] mol dm^{-3}	[Y] mol dm^{-3}	Rate of reaction mol $dm^{-3} s^{-1}$
1	0.4	0.24	1.2×10^{-4}
2	0.8	0.24	2.4×10^{-4}
3	0.4	0.12	3.0×10^{-5}

The overall order of reaction is:

A. 1

B. 2

C. 3

D. 4

23. Which units could be used for the rate of a chemical reaction?

A. mol dm^{-3} min

B. mol^{-1} min^{-1}

C. dm^3 min

D. mol dm^{-3} min^{-1}

24. 10 cm^3 of liquid hexane is placed in a closed 1 dm^3 container at 298K. Which change would increase the equilibrium vapour pressure of the hexane in the container?

A. Putting the container in a refrigerator

B. Adding 10 cm^3 of hexane to the container

C. Reducing the volume of the container to 0.5 dm^3

D. Putting the container in a water bath at 308 K

25. Which change will increase the equilibrium concentration of sulfur trioxide in this reaction?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = \text{negative}$$

A. Decreasing the concentration of oxygen

B. Increasing the pressure

C. Using a catalyst

D. Increasing the temperature

Chem 7/Q# 130//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

22. Which equilibrium reaction shifts to the product side when the temperature is increased at constant pressure **and** to the reactant side when the total pressure is increased at constant temperature?

A. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} < 0$

B. $N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H^{\ominus} > 0$

C. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^{\ominus} < 0$

D. $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H^{\ominus} > 0$

23. A mixture of 2.0 mol of H_2 and 2.0 mol of I_2 is allowed to reach equilibrium in the gaseous state at a certain temperature in a 1.0 dm^3 flask. At equilibrium, 3.0 mol of HI are present. What is the value of K_c for this reaction?

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

A. $K_c = \dfrac{(3.0)^2}{(0.5)^2}$

B. $K_c = \dfrac{3.0}{(0.5)^2}$

C. $K_c = \dfrac{(3.0)^2}{(2.0)^2}$

D. $K_c = \dfrac{(0.5)^2}{(3.0)^2}$

Chem 7/Q# 131//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

8. Which statements explain why a catalyst is used in the Contact process (shown below)?

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

I. A catalyst lowers the activation energy.

II. A catalyst moves the position of equilibrium towards the product.

III. A catalyst allows the same rate to be achieved at a lower temperature.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 7/Q# 132//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

23. What is the equilibrium constant expression, K_c, for this reaction?

$$2NO(g) + H_2(g) \rightleftharpoons N_2O(g) + H_2O(g)$$

A. $K_c = \dfrac{[N_2O]+[H_2O]}{2[NO]+[H_2]}$

B. $K_c = \dfrac{[NO]^2\,[H_2]}{[N_2O][H_2O]}$

C. $K_c = \dfrac{[2NO]+[H_2]}{[N_2O]+[H_2O]}$

D. $K_c = \dfrac{[N_2O][H_2O]}{[NO]^2\,[H_2]}$

Chem 7/Q# 133//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

22. Which statement is correct for a reversible reaction when $K_c >> 1$?

A. The reaction almost goes to completion.

B. The reaction hardly occurs.

C. Equilibrium is reached in a very short time.

D. At equilibrium, the rate of the forward reaction is much higher than the rate of the backward reaction.

Chem 7/Q# 134//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

23. Which of the following will shift the position of equilibrium to the right in the Haber process?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92.6\,kJ$$

I. Decreasing the concentration of $NH_3(g)$

II. Decreasing the temperature

III. Increasing the pressure

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 7/Q# 135//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

23. Hydrogen and iodine react in a closed vessel to form hydrogen iodide.

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

At 350 °C $K_c = 60$
At 445 °C $K_c = 47$

Which statement describes and explains the conditions that favour the formation of hydrogen iodide?

A. Increased temperature as the forward reaction is exothermic, and increased pressure as there are two gaseous reactants and only one gaseous product

B. Increased temperature as the forward reaction is endothermic, and pressure has no effect as there are equal amounts, in mol, of gaseous reactants and products

C. Decreased temperature as the forward reaction is exothermic, and decreased pressure as there are two moles of gaseous product but only one mole of each gaseous reactant

D. Decreased temperature as the forward reaction is exothermic, and pressure has no effect as there are equal amounts, in mol, of gaseous reactants and products

Chem 7/Q# 136//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

22. Which changes occur when the temperature is decreased in the following equilibrium?

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

	Position of equilibrium	Value of K_c
A.	shifts to the right	decreases
B.	shifts to the right	increases
C.	shifts to the left	decreases
D.	shifts to the left	increases

23. When gaseous nitrosyl chloride, NOCl(g), decomposes, the following equilibrium is established:

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

2.0 mol of NOCl(g) were placed in a 1.0 dm^3 container and allowed to reach equilibrium. At equilibrium 1.0 mol of NOCl(g) was present. What is the value of K_c?

A. 0.50

B. 1.0

C. 1.5

D. 2.0

Chem 7/Q# 137//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

22. Iron(III) ions, Fe^{3+}, react with thiocyanate ions, SCN^-, in a reversible reaction to form a red solution. Which changes to the equilibrium will make the solution go red?

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons [FeSCN]^{2+}(aq) \qquad \Delta H^{\ominus} = +ve$$

Yellow Red

I. Increasing the temperature

II. Adding $FeCl_3$

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. Consider the following reversible reaction:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

What is the value of K_c for the reaction when the equilibrium concentrations are $[NO_2] = 4.0\ \text{mol dm}^{-3}$ and $[N_2O_4] = 4.0\ \text{mol dm}^{-3}$?

A. 0.25

B. 0.50

C. 2.0

D. 4.0

Chem 7/Q# 138//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

21. What happens to the position of equilibrium and the value of K_c when the temperature is increased in the following reaction?

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +87.9\ \text{kJ mol}^{-1}$$

	Position of equilibrium	Value of K_c
A.	shifts towards reactants	decreases
B.	shifts towards reactants	increases
C.	shifts towards products	decreases
D.	shifts towards products	increases

Chem 7/Q# 139//**IB/Paper 1/2011/w/Time Zone 0/Higher Level/**

23. Which are characteristics of a dynamic equilibrium?

I. Amounts of products and reactants are constant.

II. Amounts of products and reactants are equal.

III. The rate of the forward reaction is equal to the rate of the backward reaction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 7/Q# 140//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

23. The reaction below represents the Haber process for the industrial production of ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\,kJ$$

The optimum conditions of temperature and pressure are chosen as a compromise between those that favour a high yield of ammonia and those that favour a fast rate of production. Economic considerations are also important.

Which statement is correct?

A. A higher temperature would ensure a higher yield and a faster rate.

B. A lower pressure would ensure a higher yield at a lower cost.

C. A lower temperature would ensure a higher yield and a faster rate.

D. A higher pressure would ensure a higher yield at a higher cost.

Chem 7/Q# 141//**IB/Paper 1/2011/s/Time Zone 1/Higher Level/**

24. Which statement about chemical equilibria implies they are dynamic?

A. The position of equilibrium constantly changes.

B. The rates of forward and backward reactions change.

C. The reactants and products continue to react.

D. The concentrations of the reactants and products continue to change.

Chem 7/Q# 142//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

22. What is the effect of an increase of temperature on the yield and the equilibrium constant for the following reaction?

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(l) \qquad \Delta H^{\ominus} = -128\,kJ$$

	Yield	Equilibrium constant
A.	Increases	Increases
B.	Increases	Decreases
C.	Decreases	Increases
D.	Decreases	Decreases

Chem 7/Q# 143//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

23. 0.50 mol of $I_2(g)$ and 0.50 mol of $Br_2(g)$ are placed in a closed flask. The following equilibrium is established.

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

The equilibrium mixture contains 0.80 mol of IBr(g). What is the value of K_c?

A. 0.64

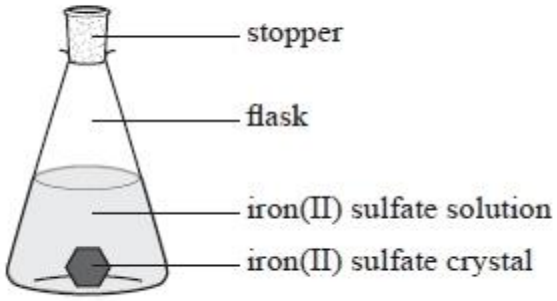
B. 1.3

C. 2.6

D. 64

Chem 7/Q# 144//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

23. Which statement is correct for a crystal of iron(II) sulfate in a state of equilibrium with a saturated solution of iron(II) sulfate?



A. The colour of the solution darkens as the crystal continues to dissolve.

B. The concentration of the iron(II) sulfate solution increases as the water evaporates.

C. The shape of the iron(II) sulfate crystal does not change.

D. The colour of the solution does not change but the shape of the crystal may change.

Chem 7/Q# 145//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

22. An increase in temperature increases the amount of chlorine present in the following equilibrium.

$$PCl_5(s) \rightleftharpoons PCl_3(l) + Cl_2(g)$$

What is the best explanation for this?

A. The higher temperature increases the rate of the forward reaction only.

B. The higher temperature increases the rate of the reverse reaction only.

C. The higher temperature increases the rate of both reactions but the forward reaction is affected more than the reverse.

D. The higher temperature increases the rate of both reactions but the reverse reaction is affected more than the forward.

Chem 7/Q# 146//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

24. Consider the following reversible reaction.

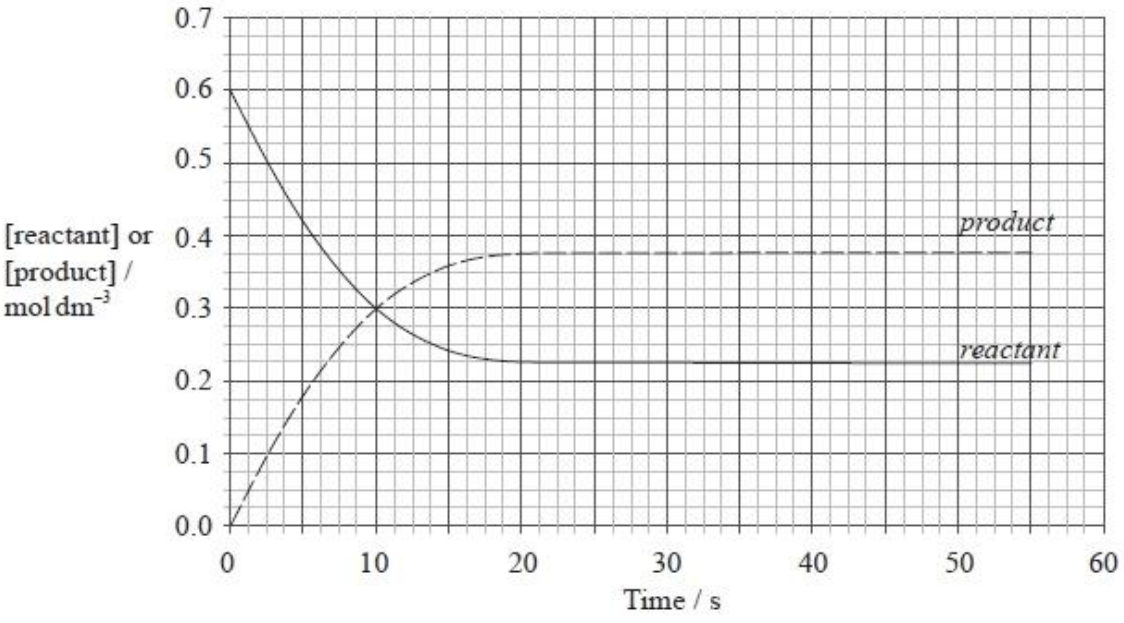
$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$

What will happen to the position of equilibrium and the value of K_c when more H^+ ions are added at constant temperature?

	Position of equilibrium	Value of K_c
A.	shifts to the left	decreases
B.	shifts to the right	increases
C.	shifts to the right	does not change
D.	shifts to the left	does not change

Chem 7/Q# 147//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

25. The graph below shows how the concentrations of the reactant and product in a reversible reaction change with time.



When is the reaction at equilibrium?

I. Time = 10 s

II. Time = 20 s

III. Time = 55 s

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 7/Q# 148//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

27. The equation for a reversible process can be represented in two ways:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad K_{c1}$$

$$HI(g) \rightleftharpoons \tfrac{1}{2}H_2(g) + \tfrac{1}{2}I_2(g) \qquad K_{c2}$$

What is the relationship between the equilibrium constants K_{c1} and K_{c2}?

A. $K_{c1} = K_{c2}$

B. $K_{c1} = \frac{1}{2K_{c2}}$

C. $K_{c1} = \frac{1}{2K_{c2}^{\ 2}}$

D. $K_{c1} = \frac{1}{K_{c2}^{\ 2}}$

Chem 7/Q# 149//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

25. Which change will increase the equilibrium concentration of sulfur trioxide in this reaction?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = \text{negative}$$

A. Decreasing the concentration of oxygen

B. Increasing the pressure

C. Using a catalyst

D. Increasing the temperature

Chem 8/Q# 150//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

24. Which definition of a base is correct?

A. A Lewis base accepts a proton.

B. A Brønsted–Lowry base accepts an electron pair.

C. A Brønsted–Lowry base donates an electron pair.

D. A Lewis base donates an electron pair.

25. A student adds 0.3 g of magnesium metal to equal volumes of hydrochloric acid and ethanoic acid of the same concentrations in separate flasks. Which statement is correct?

A. Hydrochloric acid reacts more rapidly as it has a higher pH than ethanoic acid.

B. A greater total volume of H_2 gas is produced with hydrochloric acid than with ethanoic acid.

C. The same total volume of H_2 gas is produced with both hydrochloric acid and ethanoic acid.

D. Ethanoic acid reacts more slowly because it has a lower pH than hydrochloric acid.

26. Which compound will produce an aqueous solution which has a pH greater than 7?

A. $CuSO_4$

B. $FeCl_3$

C. Na_2CO_3

D. NH_4NO_3

27. Methylamine acts as a weak base when it reacts with water. For a diluted aqueous solution, what is the K_b expression for this reaction?

A. $K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$

B. $K_b = \frac{[CH_3NH_2][H_2O]}{[CH_3NH_3^+][OH^-]}$

C. $K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2][H_2O]}$

D. $K_b = \frac{[CH_3NH_2]}{[CH_3NH_3^+][OH^-]}$

28. A buffer solution is formed by mixing equal volumes of $1.00\,mol\,dm^{-3}$ propanoic acid and $0.500\,mol\,dm^{-3}$ potassium propanoate.

What is the concentration, in $mol\,dm^{-3}$, of $[H^+(aq)]$ in this buffer solution? (K_a for propanoic acid is 1.30×10^{-5}.)

A. 2.60×10^{-5}

B. 1.95×10^{-5}

C. 1.30×10^{-5}

D. 0.650×10^{-5}

29. The acid–base indicator phenol red, HIn, changes colour from yellow to red over a pH range of 6.6–8.2. Which statement is correct?

A. In a strongly acidic solution $[HIn] < [In^-]$.

B. The pK_a of phenol red is between 6.6 and 8.2.

C. The In^- ions are yellow.

D. Phenol red would be a suitable indicator for the titration of a strong acid and a weak base.

Chem 8/Q# 151//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

25. Which compound reacts with calcium oxide, CaO?

A. K_2O

B. Na_2O

C. SO_2

D. MgO

26. What is the conjugate base of phenol, C_6H_5OH?

A. $C_6H_4^- - OH$

B. $C_6H_5 - \overset{+}{O}H_2$

C. $C_6H_5 - O^-$

D. $C_6H_6^+ - OH$

27. Which compounds can be mixed together as aqueous solutions of equal volume and concentration to form an acidic buffer solution?

A. Sodium hydrogensulfate and sulfuric acid

B. Sodium propanoate and propanoic acid

C. Ammonium chloride and ammonia solution

D. Sodium chloride and hydrochloric acid

28. Which statements about an acid–base indicator are correct?

I. It can be a weak acid.

II. It is a substance in which the conjugate acid/base pair are different colours.

III. It can be a weak base.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. What is the expression for the ionic product constant of water, K_w?

A. $K_w = K_a \times K_b$

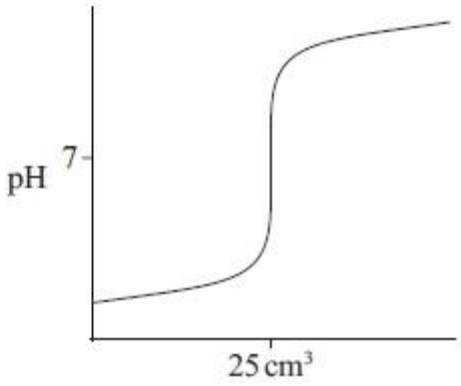
B. $K_w = K_a + K_b$

C. $K_w = \frac{K_a}{K_b}$

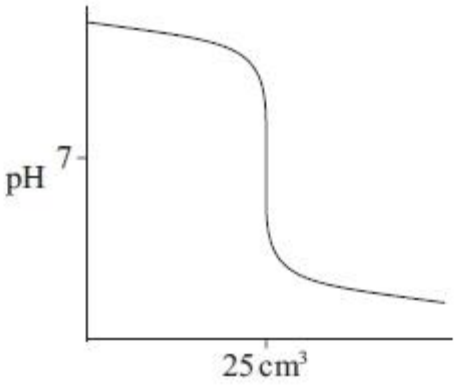
D. $K_w = K_a - K_b$

30. Which graph would be obtained by adding $0.10\,mol\,dm^{-3}$ HCl(aq) to $25\,cm^3$ of $0.10\,mol\,dm^{-3}$ NaOH(aq)?

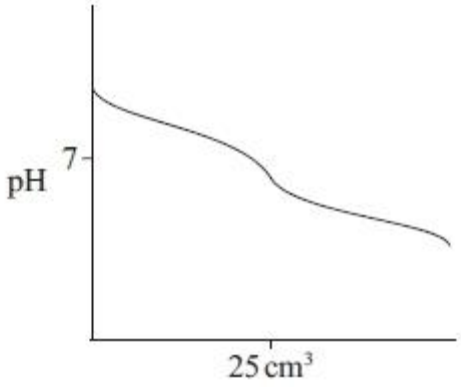
A.



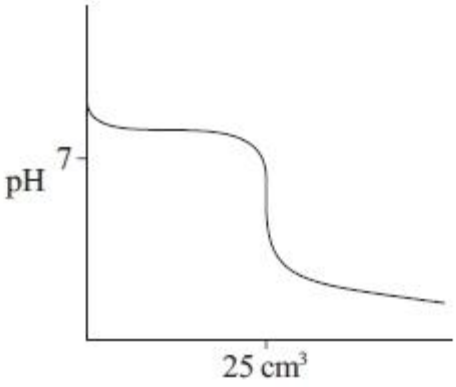
B.



C.



D.



Chem 8/Q# 152//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

24. In which reaction does H_2O act as a Lewis base but **not** as a Brønsted–Lowry base.

A. $H_2O + NH_4^+ \rightarrow H_3O^+ + NH_3$

B. $H_2O + CaO \rightarrow Ca^{2+} + 2OH^-$

C. $H_2O + [Fe(H_2O)_6]^{3+} \rightarrow Fe[(OH)(H_2O)_5]^{2+} + H_3O^+$

D. $6H_2O + [Ni(NH_3)_6]^{2+} \rightarrow 6NH_3 + [Ni(H_2O)_6]^{2+}$

25. A solution of $50\,cm^3$ hydrochloric acid has a pH of 4. What is the final pH if $450\,cm^3$ of water is added?

A. 3

B. 4

C. 5

D. 6

26. The pK_b of HS^- is 7.08. What is its conjugate acid and what is the K_a value of the acid?

	Conjugate acid	K_a
A.	H_2S	$10^{-6.92}$
B.	H_2S	6.92
C.	S^{2-}	$10^{-6.92}$
D.	S^{2-}	6.92

27. Which mixture of solutions can be used to prepare a buffer solution?

A. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $100.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_3

B. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_3

C. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $100.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_4Cl

D. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_4Cl

24. In which reaction does H_2O act as a Lewis base but **not** as a Brønsted–Lowry base.

A. $H_2O + NH_4^+ \rightarrow H_3O^+ + NH_3$

B. $H_2O + CaO \rightarrow Ca^{2+} + 2OH^-$

C. $H_2O + [Fe(H_2O)_6]^{3+} \rightarrow Fe[(OH)(H_2O)_5]^{2+} + H_3O^+$

D. $6H_2O + [Ni(NH_3)_6]^{2+} \rightarrow 6NH_3 + [Ni(H_2O)_6]^{2+}$

25. A solution of $50\,cm^3$ hydrochloric acid has a pH of 4. What is the final pH if $450\,cm^3$ of water is added?

A. 3

B. 4

C. 5

D. 6

26. The pK_b of HS^- is 7.08. What is its conjugate acid and what is the K_a value of the acid?

	Conjugate acid	K_a
A.	H_2S	$10^{-6.92}$
B.	H_2S	6.92
C.	S^{2-}	$10^{-6.92}$
D.	S^{2-}	6.92

27. Which mixture of solutions can be used to prepare a buffer solution?

A. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $100.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_3

B. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_3

C. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $100.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_4Cl

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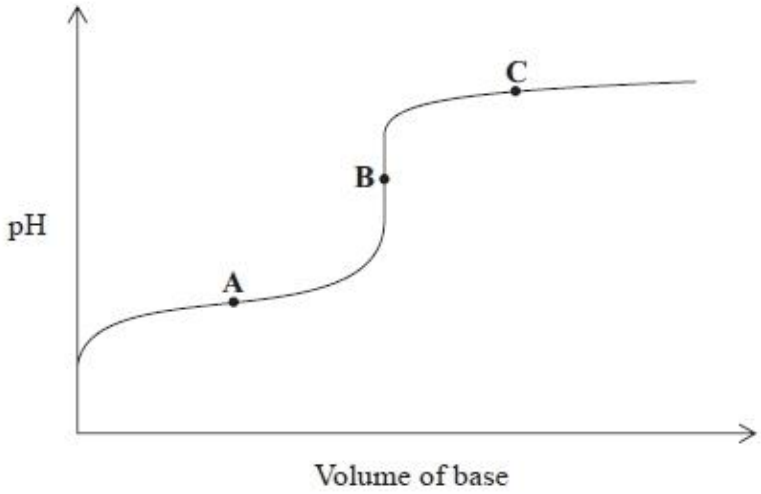
C. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $100.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_4Cl

D. $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ HCl and $50.0\,cm^3$ $0.100\,mol\,dm^{-3}$ NH_4Cl

28. A weak acid is titrated with a strong base. Which statement is true for the titration curve?



A. **A** is the equivalence point.

B. The pH at **A** equals the pK_a of the acid.

C. The pH at **B** equals 7.

D. **C** is in the buffer region.

29. Methyl orange is an indicator which changes its colour from red to yellow in a pH range of 3.2 – 4.4. For which titration would methyl orange be a suitable indicator?

A. Iodine and sodium thiosulfate solution

B. Hydrochloric acid and ammonia solution

C. Ethanoic acid and sodium hydroxide solution

D. Ethanoic acid and ammonia solution

Chem 8/Q# 153//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

25. What are the conjugate acid–base pairs in the following reaction?

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_2CO_3(aq)$$

	Brønsted–Lowry acid	Brønsted–Lowry base	Conjugate acid	Conjugate base
A.	$HCO_3^-(aq)$	$H_2O(l)$	$H_2CO_3(aq)$	$OH^-(aq)$
B.	$H_2CO_3(aq)$	$OH^-(aq)$	$HCO_3^-(aq)$	$H_2O(l)$
C.	$H_2O(l)$	$HCO_3^-(aq)$	$H_2CO_3(aq)$	$OH^-(aq)$
D.	$H_2O(l)$	$HCO_3^-(aq)$	$OH^-(aq)$	$H_2CO_3(aq)$

26. Which group of three compounds contains only weak acids and bases?

A.	$Ba(OH)_2$	CH_3NH_2	CH_3COOH
B.	$CH_3CH_2CH_2COOH$	$CH_3CH_2NH_2$	$HCOOH$
C.	NH_3	HNO_3	CH_3CH_2COOH
D.	NH_3	$NaOH$	H_2CO_3

27. What is the relationship between pK_a, pK_b and pK_w for a conjugate acid–base pair?

A. $pK_a = pK_w + pK_b$

B. $pK_a = pK_w - pK_b$

C. $pK_a \times pK_b = pK_w$

D. $\frac{pK_a}{pK_b} = pK_w$

28. The table below shows data for the K_a and pK_b values for some acids and bases at 298 K.

Acid	K_a	Base	pK_b
HClO	2.9×10^{-8}	NH_3	4.75
$C_6H_5CH_2COOH$	4.9×10^{-5}	$C_6H_5NH_2$	9.13

Which two formulas represent the weakest acid and the weakest base in the table?

A. HClO and $C_6H_5NH_2$

B. $C_6H_5CH_2COOH$ and NH_3

C. $C_6H_5CH_2COOH$ and $C_6H_5NH_2$

D. HClO and NH_3

29. Which pair of compounds could be used to make a buffer solution (assuming appropriate molar ratios)?

A. KCl and HCl

B. NaCl and HCl

C. $KHSO_4$ and H_2SO_4

D. CH_3COONa and CH_3COOH

30. Which salts form acidic solutions when dissolved in water?

I. NH_4Cl

II. $Cr(NO_3)_3$

III. CH_3COONa

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 8/Q# 154//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

26. Which of the following is an example of a Lewis acid–base reaction, but not a Brønsted–Lowry acid–base reaction?

A. $2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

B. $Co(H_2O)_6^{2+}(aq) + 4HCl(aq) \rightarrow CoCl_4^{2-}(aq) + 4H^+(aq) + 6H_2O(l)$

C. $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$

D. $CH_3COO^-(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + OH^-(aq)$

27. Which list contains only strong bases?

A. ammonia, sodium hydroxide, ethylamine

B. potassium hydroxide, ammonia, sodium hydroxide

C. lithium hydroxide, potassium hydroxide, barium hydroxide

D. ammonia, ethylamine, barium hydroxide

28. The pK_b value of ammonia is 4.75 at 298 K. What is the pK_a value of the ammonium ion?

A. $\frac{10^{-14}}{4.75}$

B. $\frac{14.00}{4.75}$

C. $14.00 - 4.75$

D. $\frac{10^{-14}}{10^{-4.75}}$

29. The K_a values of four weak acids W, X, Y and Z are listed below.

W $K_a = 1.35 \times 10^{-3}$

X $K_a = 4.47 \times 10^{-2}$

Y $K_a = 9.33 \times 10^{-6}$

Z $K_a = 1.47 \times 10^{-5}$

What is the correct order of **increasing** strength as acids?

A. X < W < Z < Y

B. W < Z < X < Y

C. Y < X < Z < W

D. Y < Z < W < X

24. In which equilibria are the conjugate acid–base pairs correctly labelled?

I. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$
Base 1 Acid 2 Acid 1 Base 2

II. $HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$
Base 1 Acid 2 Acid 1 Base 2

III. $NH_4^+(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NH_3(aq)$
Acid 1 Base 2 Acid 2 Base 1

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

25. A solution of acid HX has a pH = 1 and a solution of acid HY has a pH = 3. Which statement **must** be correct?

A. HX is a stronger acid than HY.

B. HY is a stronger acid than HX.

C. The $[H^+]$ in the solution of HX is 100 times greater than the $[H^+]$ in the solution of HY.

D. The $[H^+]$ in the solution of HY is 100 times greater than the $[H^+]$ in the solution of HX.

26. The values of K_w, the ionic product constant of water, are:

K_w	T / °C
6.4×10^{-15}	18
1.0×10^{-14}	25

Which statements are correct?

I. The $[OH^-]$ in water is less than the $[H^+]$ at 18 °C.

II. The ionization of water is an endothermic process.

III. The pH of water is lower at 25 °C than at 18 °C.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

27. For which equilibrium can an expression for a base dissociation constant, K_b, for the forward reaction be written?

A. $NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + H_2O$

B. $F^- + H_2O \rightleftharpoons HF + OH^-$

C. $NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$

D. $HF + OH^- \rightleftharpoons H_2O + F^-$

28. Which of the following mixtures, in an aqueous solution, will produce a buffer solution?

I. $50\,cm^3$ of $0.1\,mol\,dm^{-3}$ CH_3COONa and $50\,cm^3$ of $0.1\,mol\,dm^{-3}$ CH_3COOH

II. $50\,cm^3$ of $0.1\,mol\,dm^{-3}$ NH_3 and $50\,cm^3$ of $0.1\,mol\,dm^{-3}$ NH_4Cl

III. $50\,cm^3$ of $0.1\,mol\,dm^{-3}$ NaOH and $50\,cm^3$ of $0.2\,mol\,dm^{-3}$ CH_3COOH

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. The colours of three indicators are shown in the table below.

Indicator	Colour at low pH	Colour at high pH	pH range at which colour change takes place
methyl orange	red	yellow	3.2–4.4
bromothymol blue	yellow	blue	6.0–7.6
phenolphthalein	colourless	pink	8.2–10.0

Equal volumes of these three indicators were mixed and the mixture was added to a solution of pH = 5.0. What colour would be seen?

A. Yellow

B. Orange

C. Green

D. Blue

Chem 8/Q# 156//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

24. Which substance can act as a Lewis acid but not as a Brønsted–Lowry acid?

A. HCl

B. CH_3COOH

C. BF_3

D. CF_3COOH

25. Which row correctly describes 1.0 mol dm^{-3} NaOH (aq)?

	pH	Colour in universal indicator solution	Electrical conductivity
A.	14	purple	good
B.	10	green	poor
C.	14	red	good
D.	10	blue	poor

26. For pure water at 50 °C, $K_w = 5.48 \times 10^{-14}$. What is the pH of this water?

A. 4.8

B. 6.6

C. 7.0

D. 8.2

27. Which is the strongest acid?

	Acid	pK_a
A.	chloroethanoic	2.87
B.	iodoethanoic	3.18
C.	benzoic	4.20
D.	pentanoic	4.83

28. Which salts will dissolve in water to give solutions with a pH above 7?

I. Na_2CO_3

II. CH_3COONa

III. Na_2SO_4

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. During a titration, 0.1 mol dm^{-3} sodium hydroxide is added to 0.1 mol dm^{-3} ethanoic acid. Which indicator would be the best to use as an end point indicator in this titration?

	Indicator	pH range of indicator
A.	methyl orange	3.2–4.4
B.	bromophenol blue	3.0–4.6
C.	bromothymol blue	6.0–7.6
D.	phenolphthalein	8.2–10.0

23. Which reaction represents an acid–base reaction according to the Lewis theory but not according to the Brønsted–Lowry theory?

A. $CO_3^{2-}(aq) + H_3O^+(aq) \rightleftharpoons H_2O(l) + HCO_3^-(aq)$

B. $CH_3COOH(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + CH_3COO^-(aq)$

C. $NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$

D. $CuSO_4(s) + 5H_2O(l) \rightleftharpoons CuSO_4 \cdot 5H_2O(s)$

24. Four aqueous solutions are listed below.

W. $0.100\ mol\,dm^{-3}\ HNO_3(aq)$

X. $0.001\ mol\,dm^{-3}\ HNO_3(aq)$

Y. $0.100\ mol\,dm^{-3}\ KOH(aq)$

Z. $0.001\ mol\,dm^{-3}\ KOH(aq)$

What is the correct order of **increasing** pH of these solutions?

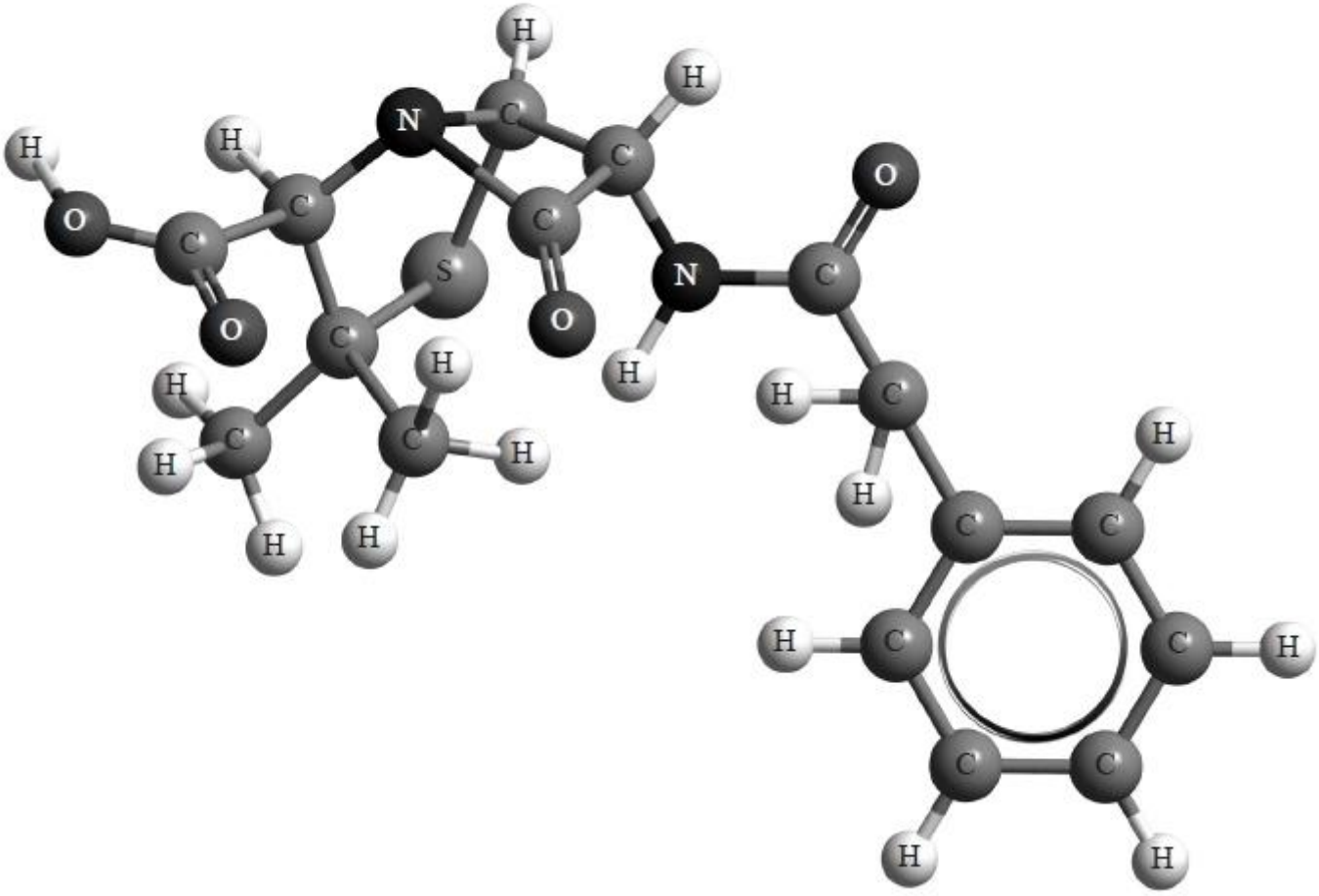
A. W < X < Y < Z

B. W < X < Z < Y

C. X < W < Y < Z

D. X < W < Z < Y

25. Penicillin G (benzyl penicillin) contains a number of different functional groups and has the following structure:



It is a weak monoprotic acid ($pK_a = 2.79$ at 298 K). At 298 K, the ionic product constant for water, $K_w = 1.00 \times 10^{-14}$. What is the value of pK_b for the conjugate base of penicillin G and which functional groups are present in penicillin G?

	pK_b	Selected functional groups in penicillin G
A.	11.21	carboxylic acid, amine
B.	2.79	carboxylic acid, amide
C.	11.21	ketone, alcohol
D.	11.21	carboxylic acid, benzene ring

26. Which mixtures are buffer solutions?

I. $KHSO_4(aq)$ and $H_2SO_4(aq)$

II. $CH_3COONa(aq)$ and $CH_3COOH(aq)$

III. $HCOOK(aq)$ and $HCOOH(aq)$

A. I and II only

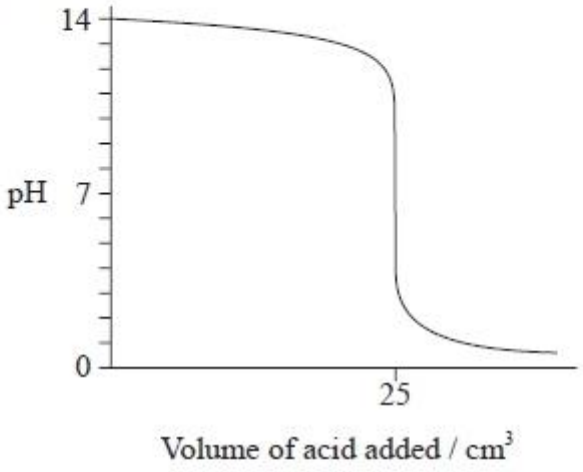
B. I and III only

C. II and III only

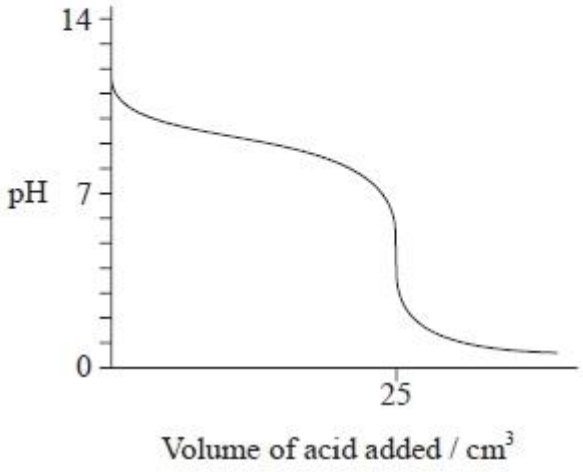
D. I, II and III

27. Which titration curve is produced by the titration of $25\ cm^3$ of $1.00\ mol\ dm^{-3}$ NaOH with $1.00\ mol\ dm^{-3}$ CH_3COOH?

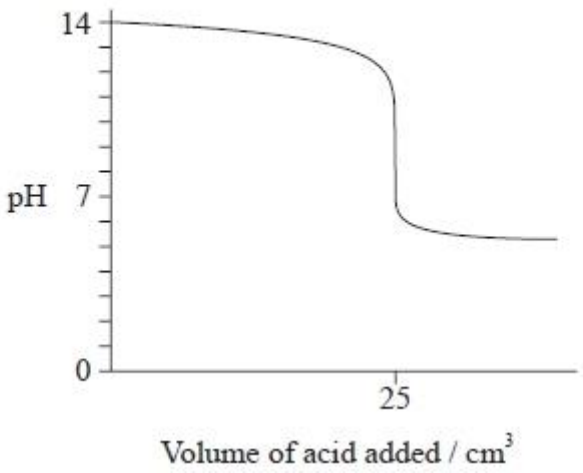
A.



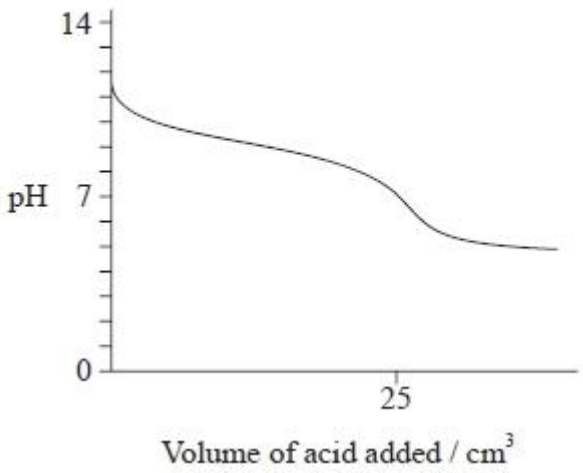
B.



C.



D.



24. Which are conjugate acid/base pairs according to the Brønsted–Lowry theory?

I. NH_4^+/NH_3

II. $HCOOH/HCOO^-$

III. H_2SO_4/SO_4^{2-}

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

25. An aqueous solution **X** reacts with a solid **Y**, to produce a flammable gas. Which of the following suggestions could substances **X** and **Y** be?

	X	Y
A.	nitric acid, HNO_3	calcium carbonate, $CaCO_3$
B.	sulfuric acid, H_2SO_4	zinc, Zn
C.	hydrochloric acid, HCl	copper, Cu
D.	sodium hydroxide solution, NaOH	aluminum oxide, Al_2O_3

26. Which is correct for a weak acid, HA, with concentration 0.01 mol dm^{-3} at 298K?

A. $[H^+] < 1\times10^{-2}$

B. $pH < 2$

C. $[OH^-] < 1\times10^{-12}$

D. $pOH > 12$

27. Which salt has the lowest pH when dissolved in water?

A. KNO_3

B. CH_3COONa

C. Na_2CO_3

D. $[Fe(H_2O)_6]Cl_3$

28. Which of the following mixtures would result in the pK_a of the acid being obtained from a direct pH measurement of the resulting solution?

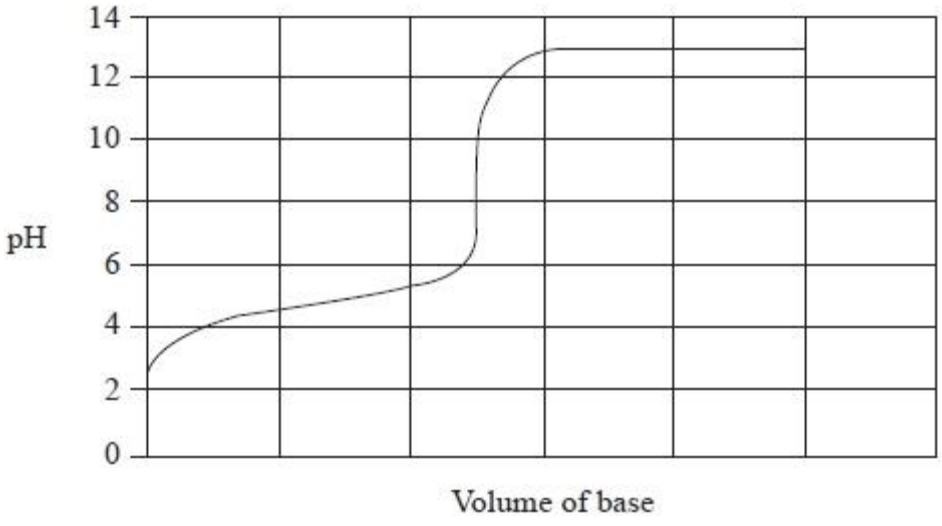
A. 25 cm^3 0.1 mol dm^{-3} HCl and 25 cm^3 0.1 mol dm^{-3} NaCl

B. 25 cm^3 0.1 mol dm^{-3} NaOH and 25 cm^3 0.1 mol dm^{-3} CH_3COOH

C. 12.5 cm^3 0.1 mol dm^{-3} CH_3COOH and 25 cm^3 0.1 mol dm^{-3} NaOH

D. 12.5 cm^3 0.1 mol dm^{-3} NaOH and 25 cm^3 0.1 mol dm^{-3} CH_3COOH

29. An aqueous solution of a weak acid containing an indicator is titrated with a strong base, resulting in the following titration curve.



At which pH does the buffer region occur?

A. Between 4.5 and 5.5

B. Between 7.5 and 9.5

C. At 9.5

D. At 12

25. Which descriptions are correct for both a Brønsted–Lowry acid and a Lewis acid?

	Brønsted–Lowry acid	Lewis acid
A.	proton donor	electron pair donor
B.	proton donor	electron pair acceptor
C.	proton acceptor	electron pair donor
D.	proton acceptor	electron pair acceptor

26. What is the pH of the solution formed when 10 cm^3 of HCl(aq) with pH 1.0 is added to 990 cm^3 of water?

A. 1.5

B. 2.0

C. 2.5

D. 3.0

27. Consider the equation for the dissociation of water:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H^\ominus = +57.3\ kJ\ mol^{-1}$$

Which statement is correct?

A. The pH of pure water is always 7.

B. At temperatures above 298 K the pH of pure water is below 7.

C. At temperatures above 298 K the pH of pure water is above 7.

D. K_w decreases with increasing temperature.

28. Which combination of 1 mol dm^{-3} solutions produces an acidic buffer?

A. 50 cm^3 HCl(aq) and 150 cm^3 NH_3(aq)

B. 100 cm^3 CH_3COOH(aq) and 50 cm^3 HCl(aq)

C. 100 cm^3 CH_3COOH(aq) and 50 cm^3 NaOH(aq)

D. 50 cm^3 CH_3COOH(aq) and 50 cm^3 NaOH(aq)

29. Which salt dissolves in water to form an acidic solution?

A. Potassium ethanoate

B. Calcium ethanoate

C. Ammonium chloride

D. Sodium carbonate

Chem 8/Q# 160//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

25. Which is **not** a conjugate acid-base pair?

A. HNO_3 and NO_3^-

B. CH_3COOH and CH_3COO^-

C. H_3O^+ and OH^-

D. HSO_4^- and SO_4^{2-}

26. The pH of a solution changes from pH = 2 to pH = 5. What happens to the concentration of the hydrogen ions during this pH change?

A. It decreases by a factor of 1000

B. It increases by a factor of 1000

C. It decreases by a factor of 100

D. It increases by a factor of 100

27. Based on information in the table below, which acid is the strongest?

	Acid	pK_a	K_a
A.	HA	2.0	–
B.	HB	–	1×10^{-3}
C.	HC	4.0	–
D.	HD	–	1×10^{-5}

28. Which combination will form a buffer solution?

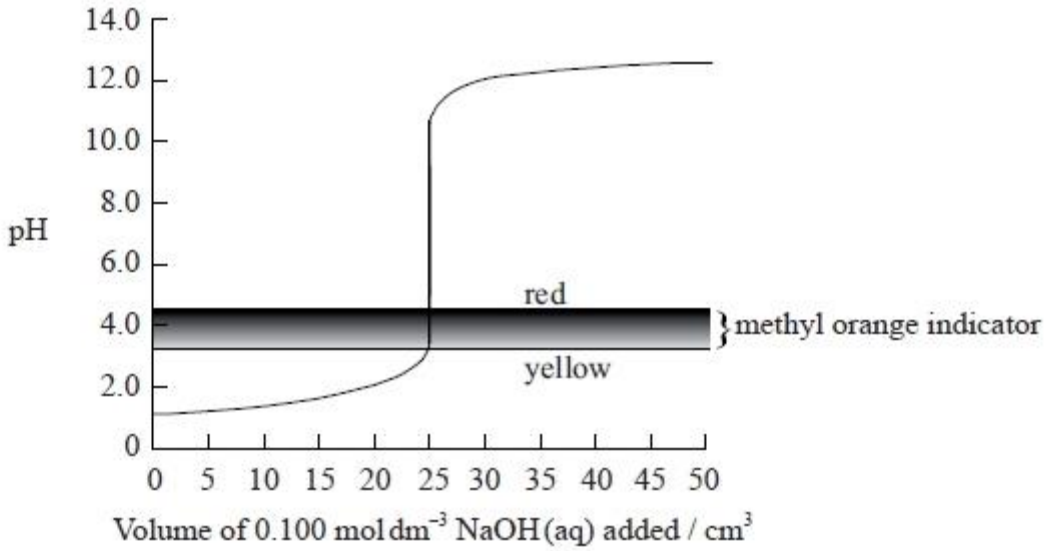
A. 100 cm^3 of 0.10 mol dm^{-3} hydrochloric acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide.

B. 100 cm^3 of 0.10 mol dm^{-3} ethanoic acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide.

C. 50 cm^3 of 0.10 mol dm^{-3} hydrochloric acid with 100 cm^3 of 0.10 mol dm^{-3} sodium hydroxide.

D. 50 cm^3 of 0.10 mol dm^{-3} ethanoic acid with 100 cm^3 of 0.10 mol dm^{-3} sodium hydroxide.

29. The graph below shows the titration curve of 25 cm^3 of 0.100 mol dm^{-3} of hydrochloric acid with sodium hydroxide, of 0.100 mol dm^{-3} concentration. The indicator methyl orange was used to determine the equivalence point. Methyl orange has a pH range of 3.2–4.4.



If the hydrochloric acid was replaced by ethanoic acid of the same volume and concentration, which property of the titration would remain the same?

A. The initial pH

B. The pH at the equivalence point

C. The volume of strong base, NaOH, needed to reach the equivalence point

D. The colour of the titration mixture just before the equivalence point is reached

26. Which salts will produce an acidic solution when dissolved in water?

I. CH_3COOK

II. NH_4NO_3

III. $Al_2(SO_4)_3$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

27. Consider the equilibrium below.

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$$

Which species represent a conjugate acid-base pair?

A. CH_3CH_2COOH and H_2O

B. H_2O and $CH_3CH_2COO^-$

C. H_3O^+ and H_2O

D. $CH_3CH_2COO^-$ and H_3O^+

28. The K_b value for a base is 5.0×10^{-2} mol dm^{-3} at 298 K. What is the K_a value for its conjugate acid at this temperature?

A. 5.0×10^{-2}

B. 2.0×10^{-6}

C. 2.0×10^{-12}

D. 2.0×10^{-13}

29. Which compounds can be mixed together as solutions of equal volume and concentration to form a buffer solution?

A. Nitric acid and potassium hydroxide

B. Nitric acid and potassium nitrate

C. Propanoic acid and potassium hydroxide

D. Propanoic acid and potassium propanoate

Chem 8/Q# 162//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

24. What is the conjugate base of H_2CO_3 according to the Brønsted-Lowry theory?

A. CO_3^{2-}

B. HCO_3^-

C. $H_3CO_3^+$

D. CO_2

25. A solution of acid A has a pH of 1 and a solution of acid B has a pH of 2. Which statement **must** be correct?

A. Acid A is stronger than acid B

B. [A] > [B]

C. The concentration of H^+ ions in A is higher than in B

D. The concentration of H^+ ions in B is twice the concentration of H^+ ions in A

26. Which mixtures act as buffer solutions?

I. 100 cm^3 0.1 mol dm^{-3} ethanoic acid and 100 cm^3 0.1 mol dm^{-3} sodium ethanoate

II. 100 cm^3 0.1 mol dm^{-3} ethanoic acid and 50 cm^3 0.1 mol dm^{-3} sodium hydroxide

III. 100 cm^3 0.1 mol dm^{-3} ethanoic acid and 100 cm^3 0.5 mol dm^{-3} sodium hydroxide

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

27. Which solutions have a pH less than 7?

I. $Na_2CO_3(aq)$

II. $[Fe(H_2O)_6]Cl_3(aq)$

III. $(NH_4)_2SO_4(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

28. Equal volumes and concentrations of hydrochloric acid and ethanoic acid are titrated with sodium hydroxide solutions of the same concentration. Which statement is correct?

A. The initial pH values of both acids are equal.

B. At the equivalence points, the solutions of both titrations have pH values of 7.

C. The same volume of sodium hydroxide is needed to reach the equivalence point.

D. The pH values of both acids increase equally until the equivalence points are reached.

29. Bromophenol blue changes from yellow to blue over the pH range of 3.0 to 4.6. Which statement is correct?

A. Molecules of bromophenol blue, HIn, are blue.

B. At pH < 3.0, a solution of bromophenol blue contains more ions, In^-, than molecules, HIn.

C. The pK_a of bromophenol blue is between 3.0 and 4.6.

D. Bromophenol blue is a suitable indicator to titrate ethanoic acid with potassium hydroxide solution.

24. Which species behave as Brønsted-Lowry acids in the following reversible reaction?

$$H_2PO_4^-(aq) + CN^-(aq) \rightleftharpoons HCN(aq) + HPO_4^{2-}(aq)$$

A. HCN and CN^-

B. HCN and HPO_4^{2-}

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

D. HCN and $H_2PO_4^-$

25. Which of the following are weak acids in aqueous solution?

I. CH_3COOH

II. H_2CO_3

III. HCl

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

26. pK_w for water at 10 °C = 14.54. What is the pH of pure water at this temperature?

A. 6.73

B. 7.00

C. 7.27

D. 7.54

27. What is K_b for the aqueous fluoride ion given that K_w is 1.0×10^{-14} and K_a for HF is 6.8×10^{-4} at 298 K?

A. $\frac{1}{6.8\times10^{-4}}$

B. $(6.8\times10^{-4})(1.0\times10^{-14})$

C. $\frac{1.0\times10^{-14}}{6.8\times10^{-4}}$

D. 6.8×10^{-4}

28. Which of the following could be added to a solution of ethanoic acid to prepare a buffer?

A. Sodium hydroxide

B. Hydrochloric acid

C. Sodium chloride

D. More ethanoic acid

29. Which aqueous solution has a pH less than 7?

A. $KNO_3(aq)$

B. $Na_2CO_3(aq)$

C. $[Fe(H_2O)_6]Cl_3(aq)$

D. $CH_3COONa(aq)$

Chem 8/Q# 164//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

25. Which statement about acids is correct?

A. A Brønsted-Lowry acid donates an electron pair.

B. A Lewis acid donates a proton.

C. A Brønsted-Lowry acid accepts a proton.

D. A Lewis acid accepts an electron pair.

26. A student has equal volumes of 1.0 mol dm^{-3} sodium hydroxide and ammonia solutions. Which statement about the solutions is correct?

A. Sodium hydroxide has a lower electrical conductivity than ammonia.

B. Sodium hydroxide has a higher hydrogen ion concentration than ammonia.

C. Sodium hydroxide has a higher pH than ammonia.

D. Sodium hydroxide has a higher hydroxide ion concentration than ammonia.

27. What is the K_b expression for the reaction of ethylamine with water?

A. $K_b = [CH_3CH_2NH_3^+][OH^-]$

B. $K_b = \dfrac{[CH_3CH_2NH_3^+][OH^-]}{[CH_3CH_2NH_2]}$

C. $K_b = \dfrac{[CH_3CH_2NH_3^+][H_2O]}{[CH_3CH_2NH_2]}$

D. $K_b = [CH_3CH_2NH_2][H_2O]$

28. When these 1.0 mol dm^{-3} acidic solutions are arranged in order of increasing strength (weakest first), what is the correct order?

acid in solution X	$K_a = 1.74\times10^{-5}$ mol dm^{-3} at 298 K
acid in solution Y	$K_a = 1.38\times10^{-3}$ mol dm^{-3} at 298 K
acid in solution Z	$K_a = 1.78\times10^{-5}$ mol dm^{-3} at 298 K

A. X < Z < Y

B. X < Y < Z

C. Z < X < Y

D. Y < X < Z

29. Consider an acid-base indicator solution.

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

What is the effect on this acid-base indicator when sodium hydroxide solution is added to it?

A. Equilibrium shifts to the right and more of colour B is seen.

B. Equilibrium shifts to the left and more of colour B is seen.

C. Equilibrium shifts to the right and more of colour A is seen.

D. Equilibrium shifts to the left and more of colour A is seen.

Chem 8/Q# 165//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

24. According to the Brønsted-Lowry theory, how does each species act in the equilibrium below?

$$CH_3COOH + H_2SO_4 \rightleftharpoons CH_3COOH_2^+ + HSO_4^-$$

	CH_3COOH	H_2SO_4	$CH_3COOH_2^+$	HSO_4^-
A.	acid	base	base	acid
B.	acid	base	acid	base
C.	base	acid	base	acid
D.	base	acid	acid	base

25. If 20 cm^3 samples of 0.1 mol dm^{-3} solutions of the acids below are taken, which acid would require a different volume of 0.1 mol dm^{-3} sodium hydroxide for complete neutralization?

A. Nitric acid

B. Sulfuric acid

C. Ethanoic acid

D. Hydrochloric acid

26. Which mixture of acid and alkali would produce a buffer solution?

	Acid	Alkali
A.	40 cm^3 0.1 mol dm^{-3} HCl	60 cm^3 0.1 mol dm^{-3} NaOH
B.	60 cm^3 0.1 mol dm^{-3} HCl	40 cm^3 0.1 mol dm^{-3} NaOH
C.	40 cm^3 0.1 mol dm^{-3} HCl	60 cm^3 0.1 mol dm^{-3} NH_3
D.	60 cm^3 0.1 mol dm^{-3} HCl	40 cm^3 0.1 mol dm^{-3} NH_3

27. Which aqueous solution would have a pH > 7?

A. Sodium sulfate

B. Ammonium nitrate

C. Sodium ethanoate

D. Aluminium nitrate

28. Which indicator would be the most appropriate for titrating aqueous ethylamine, $CH_3CH_2NH_2$, with nitric acid, HNO_3?

A. Bromophenol blue ($pK_a = 4.1$)

B. Bromothymol blue ($pK_a = 7.3$)

C. Phenol red ($pK_a = 8.0$)

D. Thymolphthalein ($pK_a = 10.0$)

Chem 8/Q# 166//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

25. Which are definitions of an acid according to the Brønsted-Lowry and Lewis theories?

	Brønsted-Lowry theory	Lewis theory
A.	proton donor	electron pair acceptor
B.	proton acceptor	electron pair acceptor
C.	proton acceptor	electron pair donor
D.	proton donor	electron pair donor

26. 100 cm^3 of a NaOH solution of pH 12 is mixed with 900 cm^3 of water. What is the pH of the resulting solution?

A. 1

B. 3

C. 11

D. 13

27. Ammonia acts as a weak base when it reacts with water. What is the K_b expression for this reaction?

A. $\frac{[NH_4^+][OH^-]}{[NH_3][H_2O]}$

B. $\frac{[NH_3][H_2O]}{[NH_4^+][OH^-]}$

C. $\frac{[NH_3]}{[NH_4^+][OH^-]}$

D. $\frac{[NH_4^+][OH^-]}{[NH_3]}$

28. The indicator, HIn is used in a titration between an acid and base. Which statement about the dissociation of the indicator, HIn is correct?

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

A. In a strongly alkaline solution, colour B would be observed.

B. In a strongly acidic solution, colour B would be observed.

C. $[In^-]$ is greater than [HIn] at the equivalence point.

D. In a weakly acidic solution colour B would be observed.

29. At the same concentration, which acid would have the lowest pH?

A. HNO_2 $K_a = 5.6\times10^{-4}\ \text{mol dm}^{-3}$

B. HF $K_a = 6.8\times10^{-4}\ \text{mol dm}^{-3}$

C. C_6H_5COOH $K_a = 6.3\times10^{-5}\ \text{mol dm}^{-3}$

D. HCN $K_a = 4.9\times10^{-10}\ \text{mol dm}^{-3}$

Chem 8/Q# 167//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

26. When equal volumes of four 0.1 mol dm^{-3} solutions are arranged in order of increasing pH (lowest pH first), what is the correct order?

A. $CH_3COOH < HNO_3 < CH_3CH_2NH_2 < KOH$

B. $HNO_3 < CH_3COOH < CH_3CH_2NH_2 < KOH$

C. $CH_3CH_2NH_2 < HNO_3 < CH_3COOH < KOH$

D. $KOH < CH_3CH_2NH_2 < CH_3COOH < HNO_3$

27. What is the correct expression for the ionic product constant of water, K_w?

A. $K_w = \dfrac{[H^+]}{[OH^-]}$

B. $K_w = \dfrac{[H_2O]}{[H^+][OH^-]}$

C. $K_w = [H^+]+[OH^-]$

D. $K_w = [H^+][OH^-]$

28. Which mixtures could act as buffers?

I. NaOH (aq) and HCl (aq)

II. NaOH (aq) and CH_3COOH (aq)

III. HCl (aq) and CH_3COONa (aq)

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. What is the approximate pH of a 0.01 mol dm^{-3} ammonia solution?

A. 2

B. More than 2 but less than 7

C. More than 7 but less than 12

D. 12

Chem 8/Q# 168//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

28. Which combinations form buffer solutions?

I. 50 cm^3 of 0.1 mol dm^{-3} $CH_3COOH(aq)$ + 25 cm^3 of 0.1 mol dm^{-3} $NaOH(aq)$

II. 50 cm^3 of 0.1 mol dm^{-3} $CH_3COOH(aq)$ + 50 cm^3 of 0.1 mol dm^{-3} $NaOH(aq)$

III. 50 cm^3 of 0.1 mol dm^{-3} $CH_3COOH(aq)$ + 50 cm^3 of 0.1 mol dm^{-3} $CH_3COONa(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

29. What is the definition of a Brønsted-Lowry acid?

A. A substance which accepts protons

B. A substance which reacts with OH^- ions

C. A substance which has a pH below 7

D. A substance which donates H^+ ions

30. Which species can act as an acid according to the Lewis theory but not according to the Brønsted-Lowry theory?

A. NCl_3

B. HCl

C. H_2O

D. BF_3

30. Which species can act as an acid according to the Lewis theory but not according to the Brønsted-Lowry theory?

A. NCl_3

B. HCl

C. H_2O

D. BF_3

31. Which salt produces the most acidic aqueous solution?

A. KCl

B. $FeCl_3$

C. CH_3COONa

D. $NaNO_3$

Chem 8/Q# 169//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

27. Consider the ionization of water at 25 °C:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$$

However, at 37 °C, $K_w = 2.4 \times 10^{-14}$ mol^2 dm^{-6}. What can be deduced from this?

A. The pH value of pure water decreases when heated.

B. The enthalpy of ionization of water is negative.

C. The $[OH^-]$ at 37 °C is lower than 25 °C.

D. The conductivity of water at 37 °C is lower than at 25 °C.

28. What pair of solutions can be used to prepare a buffer solution?

A. $CH_3COONa\,(aq) / NaOH\,(aq)$

B. $NH_3\,(aq) / NH_4NO_3\,(aq)$

C. $NH_4Cl\,(aq) / HCl\,(aq)$

D. $HNO_3\,(aq) / NaNO_3\,(aq)$

29. Which equations represent acid-base reactions according to the Lewis theory?

I. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
II. $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$
III. $H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Which of the following compounds will produce an alkaline solution when dissolved in water?

A. NaCl

B. NH_4Cl

C. CH_3COONa

D. CH_3COONH_4

31. Which of the following are conjugate acid-base pairs?

I. $H_2O(l)$ / $OH^-(aq)$
II. $NH_4^+(aq)$ / $NH_3(aq)$
III. $HCl(aq)$ / $NaOH(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

26. Which species act as Brønsted – Lowry bases in the following reactions?

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$
$$NH_2^- + H_2O \rightleftharpoons NH_3 + OH^-$$

I. CH_3NH_2

II. $CH_3NH_3^+$

III. NH_2^-

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

27. The ionic product constant of water at 45°C is $4\times10^{-14}\,mol^2\,dm^{-6}$. Which statement is correct about pure water at 45°C?

A. $pH = 7$

B. $[H^+] = [OH^-]$

C. $[OH^-] > [H^+]$

D. $[H^+] > [OH^-]$

28. A weak monoprotic acid is 10 % dissociated in a solution of concentration $0.01\,mol\,dm^{-3}$. What is the pH value of the solution?

A. 0.1

B. 1.0

C. 2.0

D. 3.0

29. Which change increases the pH of a solution from 3 to 6?

A. Doubling the $[H^+]$

B. Halving the $[OH^-]$

C. Decreasing the $[H^+]$ by a factor of 1000

D. Decreasing the $[OH^-]$ by a factor of 1000

30. Which pair of compounds, in aqueous solution, could be used to make a buffer solution?

A. CH_3COOH and HCl

B. HCl and NaOH

C. HCl and NH_4Cl

D. HCOOH and NaOH

Chem 9/Q# 171//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

30. Which statement is correct for the following reaction?

$$2ClO_3^-(aq) + SO_2(aq) + H^+(aq) \rightarrow 2ClO_2(g) + HSO_4^-(aq)$$

A. ClO_3^- is the oxidizing agent and it undergoes reduction.

B. ClO_3^- is the reducing agent and it undergoes oxidation.

C. SO_2 is the oxidizing agent and it undergoes oxidation.

D. SO_2 is the reducing agent and it undergoes reduction.

31. Which species are produced at each electrode during the electrolysis of molten lead(II) bromide, $PbBr_2(l)$?

	Negative electrode (cathode)	Positive electrode (anode)
A.	$Br^-(l)$	$Pb^{2+}(l)$
B.	$Pb^{2+}(l)$	$Br^-(l)$
C.	$Br_2(g)$	$Pb(l)$
D.	$Pb(l)$	$Br_2(g)$

32. Consider the following standard electrode potentials.

$$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s) \qquad E^\ominus = -0.14\,V$$
$$H^+(aq) + e^- \rightleftharpoons \tfrac{1}{2}H_2(g) \qquad E^\ominus = 0.00\,V$$
$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^\ominus = +0.77\,V$$

Which species will reduce $H^+(aq)$ to $H_2(g)$ under standard conditions?

A. $Fe^{2+}(aq)$

B. $Sn^{2+}(aq)$

C. $Sn(s)$

D. $Fe^{3+}(aq)$

33. A number of molten metal chlorides are electrolysed, using the same current for the same length of time. Which metal will be produced in the greatest amount, in mol?

A. Mg

B. Al

C. K

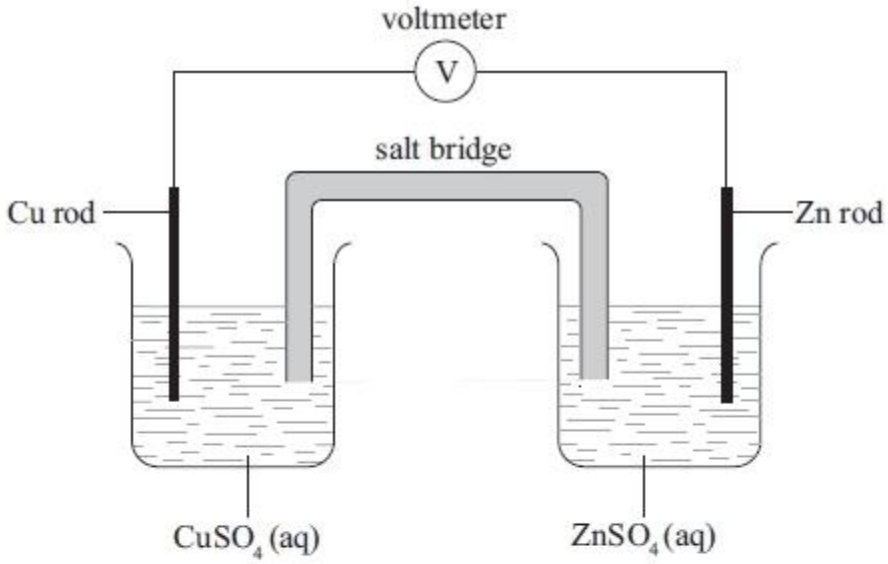
D. Ca

31. Which species are the oxidizing and reducing agents in the following reaction?

$$SO_3^{2-}(aq) + PbO_2(s) + H_2O(l) \rightarrow SO_4^{2-}(aq) + Pb(OH)_2(s)$$

	Oxidizing agent	Reducing agent
A.	PbO_2	H_2O
B.	SO_3^{2-}	PbO_2
C.	H_2O	SO_3^{2-}
D.	PbO_2	SO_3^{2-}

32. Zinc is more reactive than copper. In this voltaic cell, which species is reduced and in which direction do negative ions flow in the salt bridge?



	Species reduced	Direction of negative ion flow in salt bridge
A.	Cu^{2+}	from copper half-cell to zinc half-cell
B.	Cu^{2+}	from zinc half-cell to copper half-cell
C.	Zn^{2+}	from copper half-cell to zinc half-cell
D.	Zn^{2+}	from zinc half-cell to copper half-cell

33. Which components are used to make the standard hydrogen electrode?

A. $H_2(g), H^+(aq), Pt(s)$

B. $H_2(g), H^+(aq), Ni(s)$

C. $H_2(g), HO^-(aq), Pt(s)$

D. $H_2(g), HO^-(aq), Ni(s)$

34. What is the cell potential, in V, of the reaction below?

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

$$\tfrac{1}{2}S_4O_6^{2-}(aq) + e^- \rightleftharpoons S_2O_3^{2-}(aq) \qquad E^\ominus = +0.09\,V$$

$$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq) \qquad E^\ominus = +0.54\,V$$

A. +0.63

B. +0.45

C. −0.45

D. −0.63

Chem 9/Q# 173//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

30. At which side of the equation are electrons, H^+ ions and H_2O needed to complete the half-equation?

$$MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$$

	Electrons	H^+ ions	H_2O
A.	reactant side	reactant side	product side
B.	reactant side	product side	reactant side
C.	product side	reactant side	product side
D.	product side	product side	reactant side

31. What are the correct names for $KMnO_4$ and $K_2Cr_2O_7$, using oxidation numbers?

A. Potassium permanganate and potassium dichromate

B. Potassium manganate(IV) and potassium chromate(VII)

C. Potassium permanganate(IV) and potassium dichromate(VII)

D. Potassium manganate(VII) and potassium dichromate(VI)

32. What is an industrial use of electrolysis?

A. The production of graphite

B. The production of iron

C. The production of electric energy

D. Electroplating

33. The overall equation of a voltaic cell is:

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

The standard electrode potential for $Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$, is $-0.26\,V$. What is the standard electrode potential for the silver half-cell, $Ag^+(aq) + e^- \rightleftharpoons Ag(s)$, in V?

A. −1.32

B. −0.80

C. +0.80

D. +1.32

Chem 9/Q# 174//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

31. What is the name of MnO_2?

A. Manganese(II) oxide

B. Magnesium(II) oxide

C. Manganese(IV) oxide

D. Magnesium(IV) oxide

32. Consider the following reaction.

$$2Cr(OH)_3(s) + 6ClO^-(aq) \rightarrow 2CrO_4^{2-}(aq) + 3Cl_2(g) + 2OH^-(aq) + 2H_2O(l)$$

Which statement is correct?

A. $Cr(OH)_3$ is the oxidizing agent and the oxidation number of chromium changes from +3 to +6.

B. $Cr(OH)_3$ is the reducing agent and undergoes reduction.

C. ClO^- is the oxidizing agent and the oxidation number of chlorine changes from +1 to 0.

D. ClO^- is the reducing agent and the oxidation number of chlorine changes from −1 to 0.

33. Consider the following two standard electrode potentials at 298 K.

$$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s) \qquad E^\ominus = -0.14\,V$$
$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^\ominus = +0.77\,V$$

What is the equation and cell potential for the spontaneous reaction that occurs?

A. $2Fe^{2+}(aq) + Sn^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + Sn(s) \qquad E^\ominus = -0.91\,V$

B. $2Fe^{3+}(aq) + Sn(s) \rightarrow 2Fe^{2+}(aq) + Sn^{2+}(aq) \qquad E^\ominus = +0.91\,V$

C. $2Fe^{2+}(aq) + Sn^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + Sn(s) \qquad E^\ominus = +0.91\,V$

D. $2Fe^{3+}(aq) + Sn(s) \rightarrow 2Fe^{2+}(aq) + Sn^{2+}(aq) \qquad E^\ominus = +1.68\,V$

34. What happens during the electrolysis of concentrated aqueous potassium chloride?

I. Reduction takes place at the negative electrode (cathode).

II. Hydrogen gas is evolved at the negative electrode (cathode).

III. The pH of the electrolyte increases.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Which is the oxidizing agent in the following reaction?

$$5SO_2(g) + 2IO_3^-(aq) + 4H_2O(l) \rightarrow 5SO_4^{2-}(aq) + I_2(aq) + 8H^+(aq)$$

A. SO_2

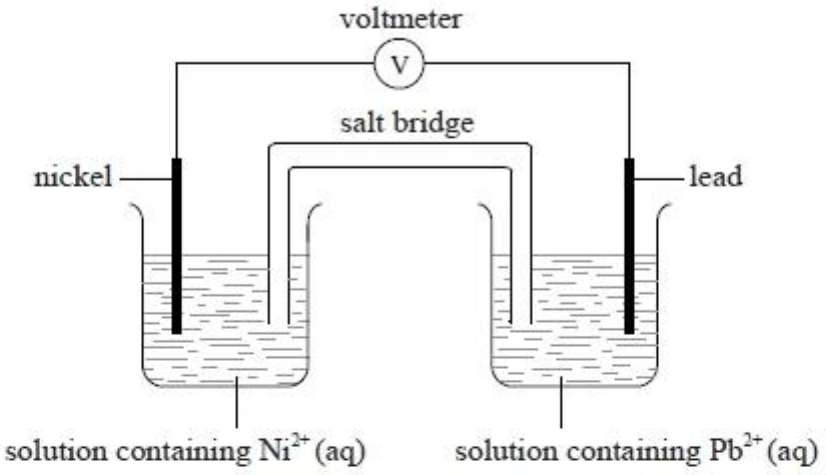
B. IO_3^-

C. H_2O

D. SO_4^{2-}

31. The overall reaction in the voltaic cell below is:

$$Ni(s) + Pb^{2+}(aq) \rightarrow Ni^{2+}(aq) + Pb(s)$$



Which statement is correct for the nickel half-cell?

A. Nickel is the positive electrode (cathode) and is reduced.

B. Nickel is the negative electrode (anode) and is reduced.

C. Nickel is the positive electrode (cathode) and is oxidized.

D. Nickel is the negative electrode (anode) and is oxidized.

32. Which statement is correct for electroplating an object with gold?

A. The object must be the negative electrode (cathode).

B. The negative electrode (cathode) must be gold.

C. The object must be the positive electrode (anode).

D. The gold electrode must be pure.

30. Which statement is correct about a reducing agent?

A. It is reduced by gaining electrons.

B. It is oxidized by gaining electrons.

C. It is oxidized by losing electrons.

D. It is reduced by losing electrons.

31. An aqueous solution of a metal salt is electrolysed. Which factor will have no effect on the mass of the metal deposited on the negative electrode (cathode), if all other variables remain constant?

A. Size of metal ion

B. Relative atomic mass of metal

C. Current

D. Charge on metal ion

32. Which are correct statements about a voltaic cell?

I. A spontaneous redox reaction occurs which converts chemical energy to electrical energy.

II. Oxidation occurs at the negative electrode (anode).

III. Electricity is conducted by the movement of electrons through the salt bridge.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

33. The standard electrode potentials of some half-reactions are given below.

$$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq) \qquad E^\ominus = +0.15\ V$$
$$\tfrac{1}{2}I_2(s) + e^- \rightleftharpoons I^-(aq) \qquad E^\ominus = +0.54\ V$$
$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^\ominus = +0.77\ V$$

Which of the following reactions will occur spontaneously?

A. Iodine reduces Fe^{3+} to Fe^{2+}

B. Iodine reduces Sn^{4+} to Sn^{2+}

C. Iodine oxidizes Fe^{2+} to Fe^{3+}

D. Iodine oxidizes Sn^{2+} to Sn^{4+}

Chem 9/Q# 177//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

30. What is the correct systematic name of MnO_2?

A. Manganese(II) oxide

B. Manganese(IV) oxide

C. Magnesium(II) oxide

D. Magnesium(IV) oxide

31. A voltaic cell is made by connecting zinc and lead half-cells. The overall equation for the reaction occurring in the cell is shown below.

$$Zn(s) + Pb^{2+}(aq) \rightarrow Pb(s) + Zn^{2+}(aq)$$

Which statements are correct when the cell produces electricity?

I. The zinc is oxidized.

II. Electrons move from zinc to lead in the external circuit.

III. The mass of the lead electrode increases.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. Consider the following standard electrode potential values:

$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^\ominus = +0.77\ V$$
$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \qquad E^\ominus = +1.51\ V$$

What is the cell potential, in V, for this reaction?

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$$

A. −2.28

B. −0.74

C. +0.74

D. +2.28

33. Consider the following standard electrode potential values:

$$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s) \qquad E^\ominus = -2.87\ V$$
$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s) \qquad E^\ominus = -0.45\ V$$
$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \qquad E^\ominus = -0.26\ V$$
$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^\ominus = +0.77\ V$$

Which reaction is spontaneous?

A. $Ca^{2+}(aq) + Ni(s) \rightarrow Ca(s) + Ni^{2+}(aq)$

B. $3Fe^{2+}(aq) \rightarrow Fe(s) + 2Fe^{3+}(aq)$

C. $Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$

D. $Fe^{2+}(aq) + Ni(s) \rightarrow Fe(s) + Ni^{2+}(aq)$

28. Consider the following reaction:

$$3Sn^{2+}(aq) + Cr_2O_7^{2-}(aq) + 2H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3SnO_2(s) + H_2O(l)$$

Which statement is correct?

A. Sn^{2+} is the oxidizing agent because it undergoes oxidation.

B. Sn^{2+} is the reducing agent because it undergoes oxidation.

C. $Cr_2O_7^{2-}$ is the oxidizing agent because it undergoes oxidation.

D. $Cr_2O_7^{2-}$ is the reducing agent because it undergoes oxidation.

29. What occurs during the operation of a voltaic cell based on the following overall reaction?

$$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$$

	External circuit	Ion movement in solution
A.	electrons move from Cu(s) to Ag(s)	$Ag^+(aq)$ move towards Cu(s)
B.	electrons move from Ag(s) to Cu(s)	$Ag^+(aq)$ move towards Ag(s)
C.	electrons move from Cu(s) to Ag(s)	$Ag^+(aq)$ move towards Ag(s)
D.	electrons move from Ag(s) to Cu(s)	$Cu^{2+}(aq)$ move towards Cu(s)

30. Consider the following standard electrode potentials:

$$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq) \qquad E^\ominus = +0.13\ V$$
$$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s) \qquad E^\ominus = -0.13\ V$$

What is the value of the cell potential, in V, for the spontaneous reaction that occurs when the two half-cells are connected together?

A. −0.26

B. 0.00

C. +0.13

D. +0.26

31. Two electrolytic cells are connected **in series** and the same current passes through each cell. The first cell contains silver electrodes in silver nitrate solution. The second cell contains copper electrodes in copper(II) sulfate solution. In one experiment 1.00 g of silver is deposited in the first cell. What mass of copper, in g, is deposited in the second cell?

A. $\frac{1.00}{107.87}$

B. $\frac{1.00}{63.55}$

C. $\frac{1.00}{107.87} \times \frac{63.55}{2}$

D. $\frac{1.00}{107.87} \times 63.55$

Chem 9/Q# 179//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

30. The equation for the redox reaction between acidified dichromate and iodide ions is shown below.

$$Cr_2O_7^{2-}(aq) + 6I^-(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(aq) + 7H_2O(l)$$

Which is the reduction half-equation?

A. $6I^-(aq) + 6e^- \rightarrow 3I_2(aq)$

B. $6I^-(aq) \rightarrow 3I_2(aq) + 6e^-$

C. $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

D. $Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 6e^-$

31. The equation for the overall reaction in a voltaic cell is:

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

Which statements are correct for this cell?

I. Cu is the positive electrode.

II. Negative ions flow from the zinc solution to the copper solution.

III. Chemical energy is converted into electrical energy during this reaction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. Which statement is correct for the following spontaneous reaction?

$$2Fe^{3+}(aq) + 2Br^{-}(aq) \rightarrow 2Fe^{2+}(aq) + Br_2(aq)$$

A. $\Delta E^{\ominus} < 0$ and Br_2 is a better oxidizing agent than Fe^{3+}.

B. $\Delta E^{\ominus} < 0$ and Br^{-} is a better reducing agent than Fe^{2+}.

C. $\Delta E^{\ominus} > 0$ and Fe^{3+} is a better oxidizing agent than Br_2.

D. $\Delta E^{\ominus} > 0$ and Fe^{2+} is a better reducing agent than Br^{-}.

33. Which combination of electrodes and electrolyte could be used to plate a spoon with silver?

	Negative electrode (cathode)	Positive electrode (anode)	Electrolyte
A.	silver	spoon	sulfuric acid solution
B.	spoon	silver	sulfuric acid solution
C.	silver	spoon	silver nitrate solution
D.	spoon	silver	silver nitrate solution

Chem 9/Q# 180//**IB/Paper 1/2011/w/Time Zone 0/Higher Level/**

30. What is the correct **decreasing** order of reactivity of the metals X, Y and Z based on the following equations?

$$XCl + Y \rightarrow YCl + X$$
$$YCl + Z \rightarrow YCl + Z$$
$$ZCl + X \rightarrow XCl + Z$$

A. X > Y > Z

B. Y > Z > X

C. Z > Y > X

D. Y > X > Z

31. Four electrolytic cells are constructed. Which cell would produce the greatest mass of metal at the negative electrode (cathode)?

	Electrolyte	Current / A	Time / s
A.	1.0 mol dm^{-3} $CuSO_4$(aq)	1.0	500
B.	1.0 mol dm^{-3} $AgNO_3$(aq)	2.0	250
C.	1.0 mol dm^{-3} $CuSO_4$(aq)	1.0	750
D.	1.0 mol dm^{-3} $AgNO_3$(aq)	1.5	250

32. Which is **not** a requirement for the standard hydrogen electrode?

A. Pressure of 101 kPa

B. 1 mol dm^{-3} sulfuric acid

C. Temperature of 298 K

D. An inert electrode such as platinum

Chem 9/Q# 181//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

30. What happens to iodine when iodate ions, IO_3^-, are converted to iodine molecules, I_2?

A. It undergoes reduction and its oxidation number changes from −1 to 0

B. It undergoes oxidation and its oxidation number changes from −1 to 0

C. It undergoes reduction and its oxidation number changes from +5 to 0

D. It undergoes oxidation and its oxidation number changes from +5 to 0

31. Consider the following reactions of three unknown metals X, Y and Z.

$$2XNO_3(aq) + Y(s) \rightarrow 2X(s) + Y(NO_3)_2(aq)$$

$$Y(NO_3)_2(aq) + Z(s) \rightarrow \text{No reaction}$$

$$2XNO_3(aq) + Z(s) \rightarrow 2X(s) + Z(NO_3)_2(aq)$$

What is the order of **increasing** reactivity of the metals (least reactive first)?

A. $X < Y < Z$

B. $X < Z < Y$

C. $Z < Y < X$

D. $Y < Z < X$

32. The standard electrode potentials for two metals are given below.

$$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s) \qquad E^\ominus = -1.66\ V$$

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \qquad E^\ominus = -0.23\ V$$

What is the equation and cell potential for the spontaneous reaction that occurs?

A. $2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq) \qquad E^\ominus = 1.89\ V$

B. $2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s) \qquad E^\ominus = 1.89\ V$

C. $2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq) \qquad E^\ominus = 1.43\ V$

D. $2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s) \qquad E^\ominus = 1.43\ V$

33. The same quantity of electricity was passed through separate molten samples of sodium bromide, NaBr, and magnesium chloride, $MgCl_2$. Which statement is true about the amounts, in mol, that are formed?

A. The amount of Mg formed is equal to the amount of Na formed.

B. The amount of Mg formed is equal to the amount of Cl_2 formed.

C. The amount of Mg formed is twice the amount of Cl_2 formed.

D. The amount of Mg formed is twice the amount of Na formed.

30. Consider the following standard electrode potentials.

$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s) \qquad E^\ominus = -0.76\ V$$

$$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq) \qquad E^\ominus = +1.36\ V$$

$$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s) \qquad E^\ominus = -2.37\ V$$

What will happen when zinc powder is added to an aqueous solution of magnesium chloride?

A. No reaction will take place.

B. Chlorine gas will be produced.

C. Magnesium metal will form.

D. Zinc chloride will form.

31. Which species could be reduced to form NO_2?

A. N_2O

B. NO_3^-

C. HNO_2

D. NO

32. What are the features of a standard hydrogen electrode?

I. A temperature of 298 K

II. A carbon electrode

III. Hydrogen gas at 1.01×10^5 Pa (1 atm) pressure

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Consider the following reaction.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

Which statement is correct?

A. MnO_4^- is the oxidizing agent and it loses electrons.

B. MnO_4^- is the reducing agent and it loses electrons.

C. MnO_4^- is the oxidizing agent and it gains electrons.

D. MnO_4^- is the reducing agent and it gains electrons.

31. The following equations indicate reactions that occur spontaneously.

$$Fe(s) + NiCl_2(aq) \rightarrow FeCl_2(aq) + Ni(s)$$

$$Zn(s) + FeCl_2(aq) \rightarrow ZnCl_2(aq) + Fe(s)$$

$$Ni(s) + PbCl_2(aq) \rightarrow NiCl_2(aq) + Pb(s)$$

Which is the **increasing** order of the reactivity of the metals?

A. Fe < Ni < Zn < Pb

B. Pb < Ni < Fe < Zn

C. Ni < Zn < Pb < Fe

D. Zn < Fe < Ni < Pb

32. A voltaic cell is made by connecting two half-cells represented by the half-equations below.

$$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s) \qquad E^\ominus = -1.19\ V$$
$$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s) \qquad E^\ominus = -0.13\ V$$

Which statement is correct about this voltaic cell?

A. Mn is oxidized and the voltage of the cell is 1.06 V.

B. Pb is oxidized and the voltage of the cell is 1.06 V.

C. Mn is oxidized and the voltage of the cell is 1.32 V.

D. Pb is oxidized and the voltage of the cell is 1.32 V.

33. For the electrolysis of aqueous copper(II) sulfate, which of the following statements is correct?

A. Cu and O_2 are produced in a mol ratio of 1:1

B. H_2 and O_2 are produced in a mol ratio of 1:1

C. Cu and O_2 are produced in a mol ratio of 2:1

D. H_2 and O_2 are produced in a mol ratio of 2:1

Chem 9/Q# 184//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

30. What is the reducing agent in the reaction below?

$$2MnO_4^-(aq) + Br^-(aq) + H_2O(l) \rightarrow 2MnO_2(s) + BrO_3^-(aq) + 2OH^-(aq)$$

A. Br^-

B. BrO_3^-

C. MnO_4^-

D. MnO_2

31. Which changes could take place at the positive electrode (cathode) in a voltaic cell?

I. $Zn^{2+}(aq)$ to $Zn(s)$

II. $Cl_2(g)$ to $Cl^-(aq)$

III. $Mg(s)$ to $Mg^{2+}(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. Consider the following standard electrode potentials.

$$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s) \qquad E^{\ominus} = -0.74\ V$$

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

What will be the cell potential, in V, of a voltaic cell in which the following reaction takes place?

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

A. −1.51

B. −0.03

C. +0.03

D. +1.51

Chem 9/Q# 185//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

30. Consider the following reaction.

$$2FeSO_4(aq) + H_2O_2(aq) + H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 2H_2O(l)$$

Which species is the oxidizing agent and which is the reducing agent?

	Oxidizing agent	Reducing agent
A.	$H_2O_2(aq)$	$H_2SO_4(aq)$
B.	$H_2O_2(aq)$	$FeSO_4(aq)$
C.	$FeSO_4(aq)$	$H_2O_2(aq)$
D.	$H_2SO_4(aq)$	$H_2O_2(aq)$

31. What conditions are necessary to directly measure a standard electrode potential ($E^{\ominus}$)?

I. A half-cell with an electrode in a 1.0 mol dm^{-3} solution of its ions.

II. Connection to a standard hydrogen electrode.

III. A voltmeter between half-cells to measure potential difference.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. What condition is necessary for the electroplating of silver, Ag, onto a steel spoon?

A. The spoon must be the positive electrode.

B. The silver electrode must be the negative electrode.

C. The spoon must be the negative electrode.

D. The electrolyte must be acidified.

Chem 9/Q# 186//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

29. Which compound contains nitrogen with an oxidation number of +3?

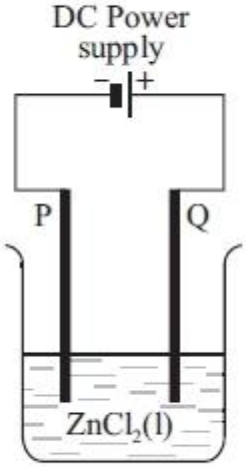
A. NH_4Cl

B. HNO_3

C. N_2O_4

D. KNO_2

30. In the electrolytic cell shown, at which electrode will chlorine form, and what is the process taking place there?



	Electrode	Process
A.	P	reduction
B.	Q	reduction
C.	P	oxidation
D.	Q	oxidation

31. Which are necessary conditions for the standard hydrogen electrode to have an $E^{\ominus}$ of exactly zero?

I. Temperature = 298 K

II. $[H^+] = 1\ \text{mol dm}^{-3}$

III. $[H_2] = 1\ \text{mol dm}^{-3}$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. How do the products compare at each electrode when aqueous 1 mol dm^{-3} magnesium bromide and molten magnesium bromide are electrolysed?

			$E^{\ominus}$ / V
$Mg^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Mg(s)$	−2.37
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	$Br^-(aq)$	+1.07
$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2O(l)$	+1.23

	Positive electrode (Anode)	Negative electrode (Cathode)
A.	same	same
B.	same	different
C.	different	same
D.	different	different

Chem 9/Q# 187//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

30. Which species is oxidized in the following reaction?

$$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$$

A. Ag^+

B. Cu

C. Ag

D. Cu^{2+}

31. Which list represents the halogens in **increasing** order of oxidizing strength (weakest oxidizing agent first)?

A. Cl_2 I_2 Br_2

B. I_2 Br_2 Cl_2

C. I_2 Cl_2 Br_2

D. Cl_2 Br_2 I_2

32. What is the cell potential, in V, for the reaction that occurs when the following two half-cells are connected?

$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s) \qquad E^\ominus = -0.44\ V$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l) \qquad E^\ominus = +1.33\ V$$

A. +0.01

B. +0.89

C. +1.77

D. +2.65

Chem 9/Q# 188//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

30. What happens at the negative electrode in a voltaic cell and in an electrolytic cell?

	Voltaic cell	Electrolytic cell
A.	oxidation	reduction
B.	reduction	oxidation
C.	oxidation	oxidation
D.	reduction	reduction

31. Which conditions are usually stated for a standard hydrogen electrode?

I. Hydrogen gas at a pressure of 1.01×10^5 Pa (1 atm)

II. 1.0 mol dm^{-3} solution of any acid

III. Temperature of 25 °C (298 K)

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. Consider these standard electrode potentials.

$$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s) \qquad E^{\ominus} = -2.36\ V$$
$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s) \qquad E^{\ominus} = -0.76\ V$$

What is the cell potential for the voltaic cell produced when the two half-cells are connected?

A. −1.60 V

B. +1.60 V

C. −3.12 V

D. +3.12 V

Chem 9/Q# 189//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

32. In which compound does manganese have the highest oxidation number?

A. $MnCl_2$

B. MnO_2

C. Mn_2O_3

D. $MnSO_4$

33. Which statement about the electrolysis of molten sodium bromide is correct?

A. Bromide ions lose electrons at the negative electrode.

B. Bromide ions gain electrons at the positive electrode.

C. Bromide ions gain electrons at the negative electrode.

D. Bromide ions move even if there is no current.

34. What is the coefficient for H^+ in the following equation?

$$3Cu(s) + _\ NO_3^-(aq) + _\ H^+(aq) \rightarrow _\ Cu^{2+}(aq) + _\ NO(g) + _\ H_2O(l)$$

A. 4

B. 8

C. 12

D. 16

35. Which conditions apply to the standard hydrogen electrode?

I. Hydrogen at a pressure of 1.01×10^5 Pa (1 atm)

II. Hydrogen at a temperature of 298 K

III. 1.00 mol dm^{-3} $H_2SO_4(aq)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 9/Q# 190//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

32. What is the oxidation number of vanadium in the compound $NaVO_3$?

A. −1

B. 0

C. +2

D. +5

33. Which statement about electrochemical cells is correct?

A. The reaction in a voltaic cell is spontaneous.

B. The reaction in an electrolytic cell is spontaneous.

C. The reaction in a voltaic cell uses electrical energy.

D. The reaction in an electrolytic cell produces electrical energy.

34. What is the coefficient for $H^+(aq)$, when this redox equation is balanced using whole numbers?

$$Cr_2O_7^{2-}(aq) + Cl^-(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + Cl_2(g) + H_2O(l)$$

A. 7

B. 2

C. 14

D. 1

35. Dilute sulfuric acid is electrolyzed using inert electrodes. What product, and in what relative amount, is produced at each electrode?

	Positive electrode	Negative electrode
A.	1 mol H_2	2 mol O_2
B.	1 mol O_2	2 mol H_2
C.	2 mol H_2	1 mol O_2
D.	2 mol O_2	1 mol H_2

Chem 9/Q# 191//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

31. During the electrolysis of aqueous sulfuric acid, 1g of hydrogen gas forms at the negative electrode. What mass in grams of oxygen forms at the positive electrode in the same time?

A. 4

B. 8

C. 16

D. 32

32. Which is the strongest oxidizing agent?

A. I_2

B. I^-

C. F_2

D. F^-

33. The following are standard electrode potentials.

$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s) \quad E^{\ominus} = -0.76\,V$$
$$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s) \quad E^{\ominus} = -1.18\,V$$

What is the $E^{\ominus}$ for this reaction?

$$Mn(s) + ZnSO_4(aq) \rightarrow MnSO_4(aq) + Zn(s)$$

A. –0.42 V

B. +0.42 V

C. –1.94 V

D. +1.94 V

34. Which compound cannot be easily oxidized using acidified potassium dichromate(VI) solution?

A. $CH_3CH_2CH_2OH$

B. $CH_3CH(OH)CH_3$

C. $(CH_3)_2CHCH_2OH$

D. $(CH_3)_3COH$

35. In which reaction does hydrogen act as an oxidizing agent?

A. $Ca + H_2 \rightarrow CaH_2$

B. $F_2 + H_2 \rightarrow 2HF$

C. $C_2H_2 + H_2 \rightarrow C_2H_4$

D. $O_2 + 2H_2 \rightarrow 2H_2O$

34. Which product is formed when bromine water is added to propene, CH_3CHCH_2?

A. $CH_3CBr_2CH_3$

B. $CH_2BrCH_2CH_2Br$

C. $CH_3CHBrCH_2Br$

D. $CH_3CH_2CH_2Br$

35. Which equation represents a propagation step in the reaction of methane with bromine?

A. $CH_4 \rightarrow CH_3\bullet + H\bullet$

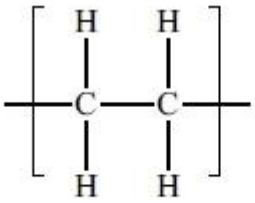
B. $CH_4 + Br\bullet \rightarrow CH_3\bullet + HBr$

C. $CH_4 + Br\bullet \rightarrow CH_3Br + H\bullet$

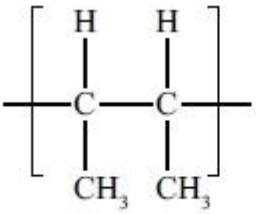
D. $CH_3\bullet + Br\bullet \rightarrow CH_3Br$

36. Which of these repeating units is present in the polymer poly(propene)?

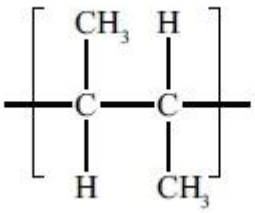
A.



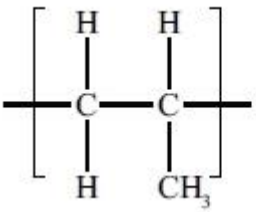
B.



C.



D.



37. Chloroethane, C_2H_5Cl, reacts with concentrated ammonia, NH_3, to form ethanamine, $C_2H_5NH_2$. Which statement about the mechanism of this reaction is correct?

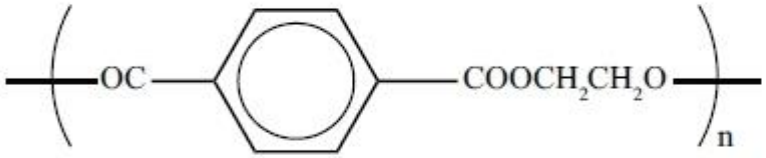
A. The reaction follows an S_N1 mechanism.

B. Homolytic fission of the carbon-chlorine bond occurs in chloroethane.

C. The reaction is unimolecular.

D. There is no charge on the transition state.

38. Which combination of monomers produces a condensation polymer with the repeating unit below?



A. C_6H_5COOH and $HOCH_2CH_2OH$

B. C_6H_5COOH and CH_3CH_2OH

C. $C_6H_4(COOH)_2$ and CH_3CH_2OH

D. $C_6H_4(COOH)_2$ and $HOCH_2CH_2OH$

39. Which type(s) of stereoisomerism, if any, is/are present in the molecule CH_2=CHCHBrCH_3?

A. Optical only

B. Geometric only

C. Optical and geometric

D. Neither optical nor geometric

Chem 10/Q# 193//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

35. In organic reaction mechanisms, what does a curly arrow represent?

A. The movement of a pair of electrons towards a nucleophile

B. The movement of a pair of electrons towards a positively charged species

C. The movement of a pair of electrons away from a positively charged species

D. The movement of a pair of electrons towards a Lewis base

36. Which properties are features of a homologous series?

I. Same general formula

II. Similar chemical properties

III. Gradation in physical properties

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

37. What does a polarimeter measure?

A. Colour of reaction mixture

B. Polarity of a molecule

C. Configuration of a molecule as R or S

D. Rotation of plane-polarized light

38. Which compound can exist as stereoisomers?

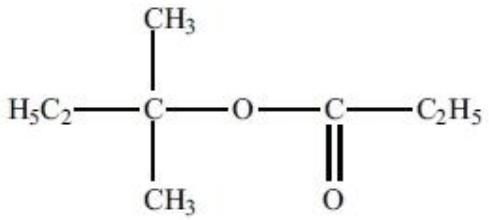
A. 1,2-dichloroethane

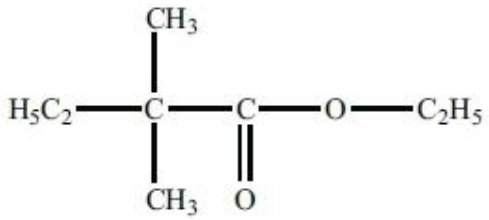
B. 1,1-dichloroethene

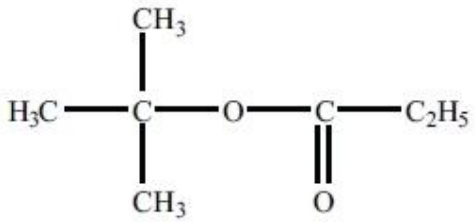
C. Butan-2-ol

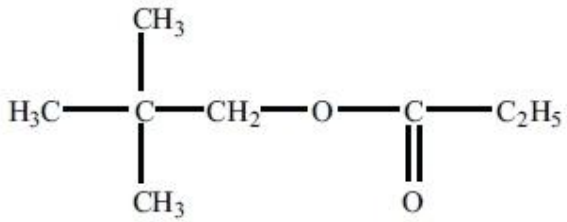
D. Propan-2-ol

39. What is the structural formula of the ester formed by reacting propanoic acid with 2-methylbutan-2-ol under appropriate conditions?

A. 

B. 

C. 

D. 

Chem 10/Q# 194//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

34. What is the IUPAC name for $(CH_3)_2COH(CH_2)_2CH_3$?

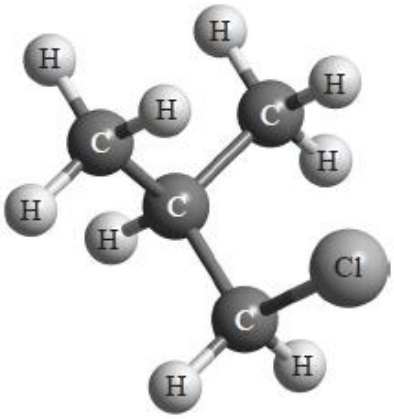
A. Hexan-3-ol

B. 2-methylpentan-2-ol

C. 2-methylpentan-3-ol

D. Dimethylpentan-1-ol

35. Which type of halogenoalkane is the substance shown below, and which type of nucleophilic reaction does it undergo with an aqueous sodium hydroxide solution?



	Type of halogenoalkane	Type of nucleophilic reaction
A.	primary	S_N1
B.	tertiary	S_N1
C.	primary	S_N2
D.	tertiary	S_N2

36. Which reaction produces **only** butan-2-ol?

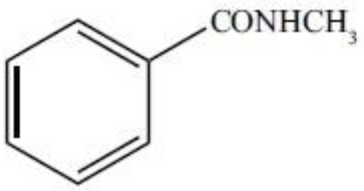
A. Addition of water to but-2-ene

B. Addition of water to but-1-ene

C. Reaction of 2-bromobutane with alcoholic sodium hydroxide

D. Reaction of 1-bromobutane with alcoholic sodium hydroxide

37. Which functional groups are present in $C_6H_5CONHCH_3$?



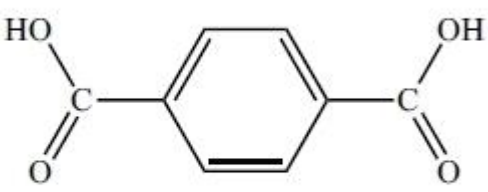
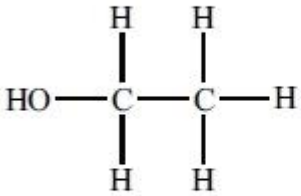
A. amide and benzene ring (phenyl)

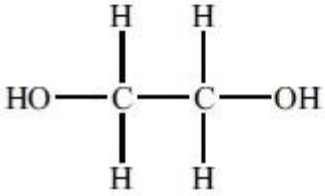
B. amine, benzene ring (phenyl) and carbonyl

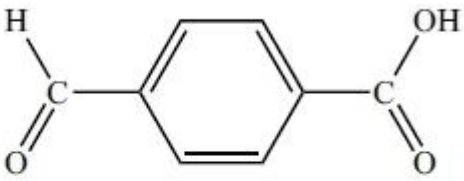
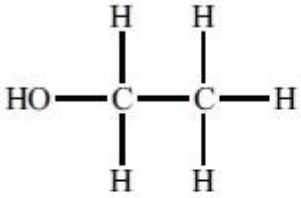
C. benzene ring (phenyl) and carbonyl

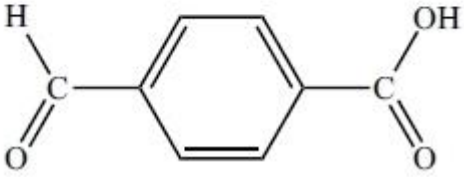
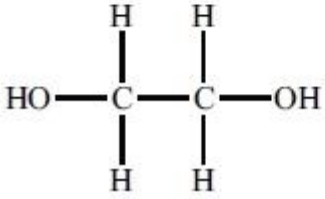
D. amine and benzene ring (phenyl)

38. Which two compounds can form a polyester?

A.  and 

B. and 

C.  and 

D.  and 

39. Which statement about isomerism is correct?

A. But-1-ene and but-2-ene are geometrical isomers.

B. But-1-ene has two geometrical isomers.

C. Butan-1-ol and butan-2-ol are optical isomers.

D. Butan-2-ol has two optical isomers.

35. What is the name of $(CH_3)_3CCOCH_3$, applying IUPAC rules?

A. 2,2-dimethylbutan-3-one

B. 3,3-dimethylbutan-2-one

C. 2,2-dimethylbutanal

D. 3,3-dimethylbutanal

36. Which functional groups are present in $C_6H_5CONHC_6H_5$?

A. Benzene ring (phenyl), amine

B. Benzene ring (phenyl), ketone, amine

C. Benzene ring (phenyl), amide

D. Alkene, amide

37. What is the product of the reaction when $CH_3CH_2CH_2CH_2CH_2CN$ is reduced by hydrogen, using a nickel catalyst under the appropriate conditions?

A. $CH_3CH_2CH_2CH_2CH_2NH_2$

B. $CH_3CH_2CH_2CH_2CH_2CH_2NH_2$

C. $CH_3CH_2CH_2CH_2CH_2CH_3$

D. $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$

38. What is the major organic product formed from the reaction of $(CH_3)_3CBr$ with a concentrated, ethanolic solution of KOH?

A. $(CH_3)_3COH$

B. $(CH_3)_2CCH_2$

C. $(CH_3)_2CO$

D. $(CH_3)_2CHO$

39. What is the organic product of the reaction between butan-1-ol and ethanoic acid on heating using concentrated sulfuric acid?

A. Butyl methanoate

B. Butyl ethanoate

C. Ethyl butanoate

D. Ethyl propanoate

Chem 10/Q# 196//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

33. What are possible products of the incomplete combustion of propan-2-ol?

A. carbon monoxide, hydrogen and carbon

B. carbon dioxide, carbon and hydrogen

C. carbon, carbon monoxide and water

D. carbon dioxide and water only

34. Which equation represents a propagation step in the mechanism for the reaction between ethane, C_2H_6, and chlorine, Cl_2, in the presence of sunlight/UV?

A. $C_2H_6 + Cl\bullet \rightarrow C_2H_5\bullet + HCl$

B. $C_2H_6 + Cl\bullet \rightarrow C_2H_5Cl + H\bullet$

C. $Cl_2 \rightarrow 2Cl\bullet$

D. $C_2H_5\bullet + Cl\bullet \rightarrow C_2H_5Cl$

35. What is the name of $CH_3CH_2CH_2CN$ applying IUPAC rules?

A. Butanamine

B. Butanamide

C. Propanenitrile

D. Butanenitrile

36. 1-bromobutane, $CH_3CH_2CH_2CH_2Br$, can be converted to 1-aminopentane, $CH_3CH_2CH_2CH_2CH_2NH_2$, in a two-step process.

$$CH_3CH_2CH_2CH_2Br \xrightarrow{\text{I}} CH_3CH_2CH_2CH_2CN$$
$$CH_3CH_2CH_2CH_2CN \xrightarrow{\text{II}} CH_3CH_2CH_2CH_2CH_2NH_2$$

What are the reagents **I** and **II**?

	I	II
A.	ammonia	hydrogen with nickel
B.	ammonia	hydrochloric acid
C.	potassium cyanide	ammonia
D.	potassium cyanide	hydrogen with nickel

37. Which halogenoalkane reacts the fastest with hydroxide ions in a nucleophilic substitution reaction?

A. 1-chlorobutane

B. 2-chloro-2-methylpropane

C. 1-iodobutane

D. 2-iodo-2-methylpropane

38. Ethylamine, $CH_3CH_2NH_2$, reacts with propanoic acid, CH_3CH_2COOH. Initially a salt is formed which, when heated at 200 °C, can form an organic product. What is the structural formula of the organic product?

A. $CH_3CH_2NHCOCH_2CH_3$

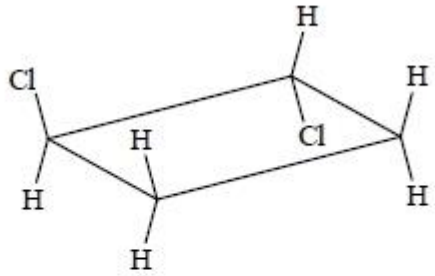
B. $CH_3CH_2NHCOOCH_2CH_3$

C. $CH_3CH_2COONHCH_2CH_3$

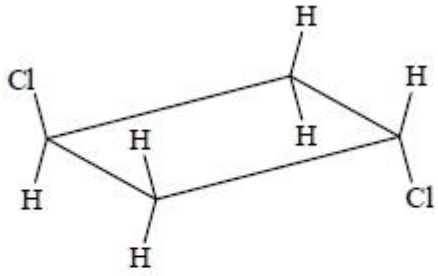
D. $CH_3CH_2COOCH_2CH_3$

39. Which structure is a geometric isomer of *cis*-1,2-dichlorocyclobutane?

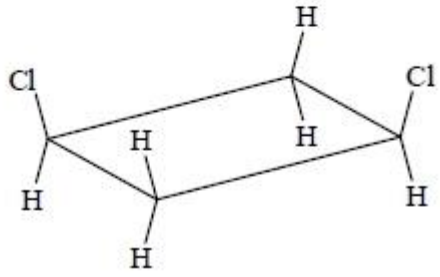
A.



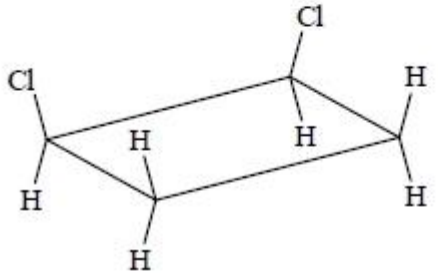
B.



C.

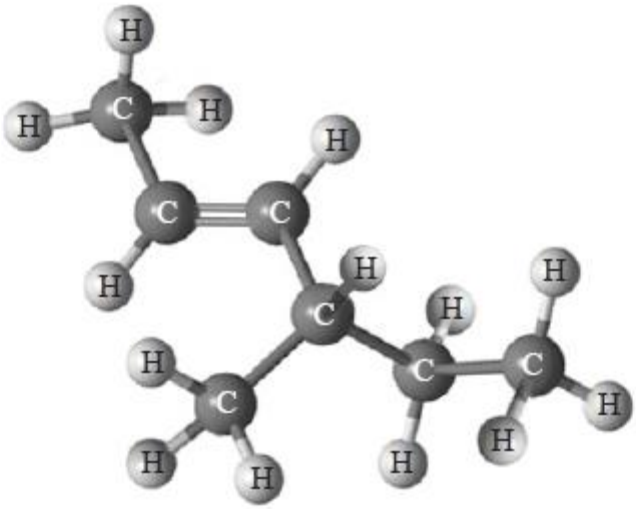


D.



Chem 10/Q# 197//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

34. What is the name of the following compound applying IUPAC rules?



A. *cis*-4-methylhex-2-ene

B. *cis*-4-ethylpent-2-ene

C. *trans*-4-methylhex-2-ene

D. *trans*-4-ethylpent-2-ene

35. Which steps are involved in the free-radical mechanism of the bromination of ethane in the presence of ultraviolet radiation?

I. $C_2H_6 + Br\bullet \rightarrow C_2H_5\bullet + HBr$

II. $C_2H_5\bullet + Br_2 \rightarrow C_2H_5Br + Br\bullet$

III. $C_2H_5\bullet + Br\bullet \rightarrow C_2H_5Br$

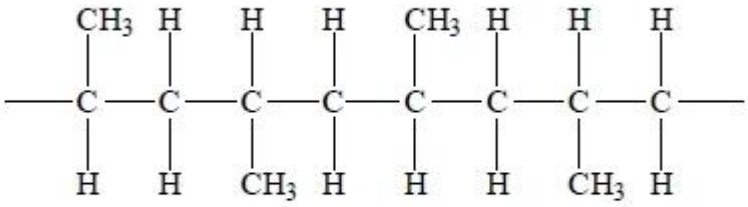
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

36. Which substance can be polymerized to produce the polymer below?



A. But-1-ene

B. But-2-ene

C. Propene

D. 2-methylpropene

37. Which factors affect the rate of nucleophilic substitution in halogenoalkanes?

I. The nature of the attacking nucleophile

II. The identity of the halogen

III. The structure of the halogenoalkane

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

38. Which molecule exhibits optical isomerism?

A. 3-chloropentane

B. 2-chlorobutane

C. 1,3-dichloropropane

D. 2-chloro-2-methylpropane

39. What is a use of the organic product formed when an alcohol and a carboxylic acid react together?

A. Pesticide

B. Lubricant

C. Flavourings in food

D. Fertilizer

Chem 10/Q# 198//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

40. $50\ cm^3$ of copper(II) sulfate solution is measured into a plastic cup using a $100\ cm^3$ measuring cylinder. Excess zinc powder is added and the temperature rise that occurs is measured with a $-10\ °C$ to $+110\ °C$ thermometer. The enthalpy change for the reaction is then calculated. Which statement is correct?

A. Systematic error will be reduced by repeating the experiment several times and averaging the results.

B. Random error will be reduced by insulating the plastic cup.

C. Random error will be reduced by using a $50\ cm^3$ graduated pipette instead of a measuring cylinder.

D. Systematic error will be increased by using a larger volume of copper(II) sulfate solution.

Chem 10/Q# 199//**IB/Paper 1/2012/w/Time Zone 0/Higher Level/**

34. Which compound has the lowest boiling point?

A. $(CH_3)_3COH$

B. $CH_3(CH_2)_3OH$

C. $(CH_3)_4C$

D. $CH_3(CH_2)_3CH_3$

35. Which compound would decolourize bromine water in the dark?

A. $CH_3COCH_2CH_3$

B. $CH_3(CH_2)_4OH$

C. $CH_3CHCHCH_3$

D. $CH_3(CH_2)_3CH_3$

36. Which statement about the oxidation of alcohols is correct?

A. Oxidation of propan-1-ol produces propanone.

B. Mild oxidation of butan-1-ol produces butanal.

C. Strong oxidation of pentan-2-ol produces pentanoic acid.

D. Mild oxidation of butan-2-ol produces butanal.

37. Which halogenoalkane will react most quickly with sodium hydroxide?

A. $CH_3CH_2CH_2CH_2Cl$

B. $CH_3CH_2CH_2CH_2Br$

C. $(CH_3)_3CCl$

D. $(CH_3)_3CBr$

38. Which would be the main product of the reaction between 1-bromobutane and concentrated sodium hydroxide in hot ethanol?

A. $CH_2CHCH_2CH_3$

B. $CH_3CHCHCH_3$

C. $CH_3CH_2CH_2CH_3$

D. $CH_3CHOHCH_2CH_3$

39. Which molecules can react to form a condensation polymer with a dicarboxylic acid such as hexanedioic acid?

I. $HOCH_2CH_2OH$

II. $CH_3CH_2NH_2$

III. $H_2N(CH_2)_6NH_2$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 10/Q# 200//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

32. What is the name of $(CH_3)_2CHCOCH_3$ applying IUPAC rules?

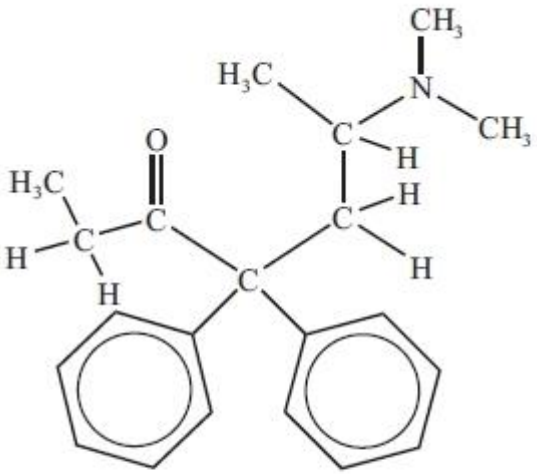
A. 3,3-dimethylpropan-2-one

B. 3-methylbutan-2-one

C. 2-methylbutan-3-one

D. 3-methylbutanal

33. The drug methadone contains several different functional groups. Which functional groups are present in methadone?



A. ketone, benzene ring, amine

B. ketone, benzene ring, amide

C. aldehyde, alkene, amide

D. aldehyde, alkene, amine

34. Which compound has the **lowest** boiling point?

A. $CH_3CH_2CH_2OH$

B. $CH_3CH_2CH_2Br$

C. CH_3CH_2COOH

D. $CH_3CH_2CH_2CH_3$

35. Which organic compounds, **Q** and **P**, are formed in the following two-stage reaction pathway?

Stage 1: $CH_3(CH_2)_3Cl \xrightarrow[\text{heat}]{NaOH(aq)} Q$

Stage 2: $Q \xrightarrow[\text{reflux}]{Cr_2O_7^{2-}(aq)/H^+(aq)} P$

	Q	P
A.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_3COOH$
B.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_2COOH$
C.	$CH_3CH_2CH{=}CH_2$	no reaction product formed
D.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_2CHO$

36. What is the organic product, **Y**, formed in the following reaction?

$$CH_3(CH_2)_3CN + 2H_2 \xrightarrow{Ni} \mathbf{Y}$$

A. $CH_3(CH_2)_3NH_2$

B. $CH_3(CH_2)_4NH_2$

C. $CH_3(CH_2)_3CH_3$

D. $CH_3(CH_2)_3COOH$

37. What organic product is formed from the reaction of benzoic acid, C_6H_5COOH, with ethylamine, $CH_3CH_2NH_2$?

A. $C_6H_5CONHCH_2CH_3$

B. $C_6H_5CONH_2$

C. $CH_3CH_2CONHC_6H_5$

D. $C_6H_5COOCH_2CH_3$

38. Which compound has a chiral carbon?

A. Propan-2-ol

B. 1-bromo-2-methylbutane

C. 3-bromopentane

D. Ethane-1,2-diol

39. What effect of optical isomers on plane-polarized light can be measured using a polarimeter?

A. Reflection

B. Emission

C. Rotation

D. Absorption

Chem 10/Q# 201//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

34. Which statements about CH_3CH_2CHO are correct?

I. It can be oxidized to CH_3CH_2COOH.

II. It can be produced by oxidation of CH_3CH_2OH.

III. It can be reduced to $CH_3CH_2CH_2OH$.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

35. Which reaction of but-2-ene produces 2-chlorobutane?

A. Addition reaction with chlorine

B. Substitution reaction with hydrogen chloride

C. Substitution reaction with chlorine

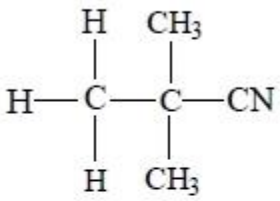
D. Addition reaction with hydrogen chloride

36. What are the correct names of the reaction types shown?

$$CH_3CH_2CH_3 \xrightarrow{I} ClCH_2CH_2CH_3 \xrightarrow{II} HOCH_2CH_2CH_3$$

	I	II
A.	nucleophilic substitution	oxidation
B.	free-radical substitution	oxidation
C.	nucleophilic substitution	nucleophilic substitution
D.	free-radical substitution	nucleophilic substitution

37. What is the name of the substance below?



A. Pentanenitrile

B. 2-methyl-2-propanenitrile

C. 2,2-dimethylpropanenitrile

D. 1,1-dimethylethanenitrile

38. What is the correct order of **increasing** rate of reaction between the following halogenoalkanes and a warm aqueous solution of sodium hydroxide?

A. $CH_3F < CH_3Cl < (CH_3)_2CHCl$

B. $CH_3Cl < CH_3F < (CH_3)_2CHCl$

C. $CH_3Cl < (CH_3)_2CHCl < CH_3F$

D. $(CH_3)_2CHCl < CH_3Cl < CH_3F$

39. Which statements are correct for the nylon shown below?

$$\left[OC(CH_2)_4CONH(CH_2)_6NH\right]_n$$

I. It is produced by condensation polymerization.

II. It is a polyamide.

III. One of its monomers is $H_2N(CH_2)_6NH_2$.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

33. Which molecule contains an ester group?

A. CH_3CH_2COOH

B. CH_3COOCH_3

C. $CH_3COCH_2CH_2OH$

D. $OHCCH_2CHO$

34. Which compound is produced in the reaction between but-2-ene and steam?

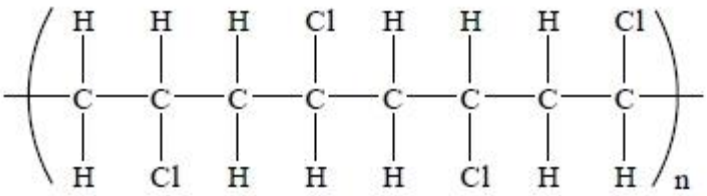
A. $CH_3CHOHCHOHCH_3$

B. $CH_2OHCH_2CH_2CH_2OH$

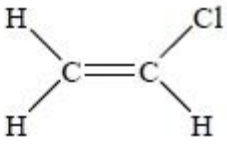
C. $CH_3CH_2CHOHCH_3$

D. $CH_3CH_2CH_2CH_2OH$

35. From which monomer is this polymer made?



A.



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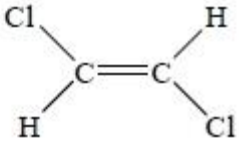

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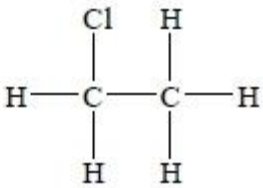

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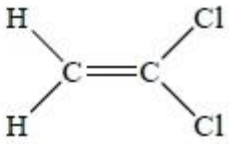


36. Which compound is the major product of the reaction when 1-bromobutane is heated with concentrated sodium hydroxide in ethanol?

A. $CH_3CHOHCH_2CH_3$

B. $CH_3CHCHCH_3$

C. $CH_3CH_2CH_2CH_2OH$

D. $CH_2CHCH_2CH_3$

37. Which halogenoalkane reacts fastest with sodium hydroxide?

A. 1-iodobutane

B. 1-chlorobutane

C. 2-chloro-2-methylpropane

D. 2-iodo-2-methylpropane

38. Which molecule exhibits optical isomerism?

A. 3-iodopentane

B. 2-iodo-2-methylpropane

C. 1,3-diiodopropane

D. 2-iodobutane

39. What is the most likely use for the organic product of the following reaction?

$$CH_3CH_2CH_2OH + CH_3CH_2CH_2COOH \rightarrow$$

A. Catalyst

B. Pesticide

C. Detergent

D. Perfume

34. Which of the structures below is an aldehyde?

A. $CH_3CH_2CH_2CH_2OH$

B. $CH_3CH_2COCH_3$

C. $CH_3CH_2COOCH_3$

D. $CH_3CH_2CH_2CHO$

35. Which type of reaction occurs when 2-iodo-2-methylpropane, $C(CH_3)_3I$, reacts with aqueous sodium hydroxide, NaOH (aq)?

A. Addition

B. Free-radical substitution

C. S_N1

D. S_N2

36. Halogenoalkanes can undergo S_N1 and S_N2 reactions with aqueous sodium hydroxide. Which halogenoalkane will react fastest with a 0.1 mol dm^{-3} solution of aqueous sodium hydroxide?

A. 2-chloro-2-methylpropane

B. 2-iodo-2-methylpropane

C. 1-chlorobutane

D. 1-iodobutane

37. Propanitrile can be prepared by reacting bromoethane with potassium cyanide. Which statement is **not** correct about the reaction between bromoethane and potassium cyanide?

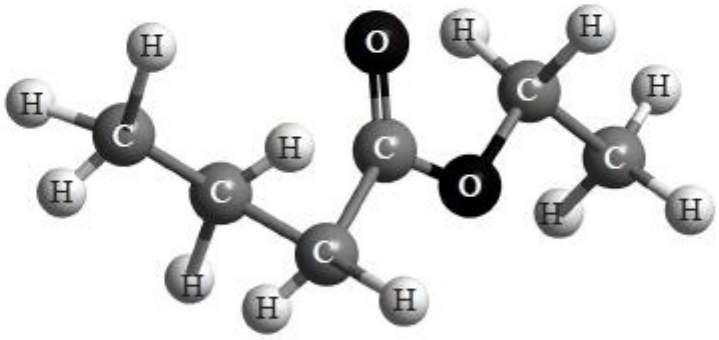
A. The reaction is bi-molecular.

B. The reaction follows the S_N2 mechanism.

C. Homolytic fission occurs between the carbon-bromine bond in bromoethane.

D. The cyanide ion, $:CN^-$, acts as a nucleophile.

38. Which reactants could be used to form the compound below?



A. Butanoic acid and ethanol

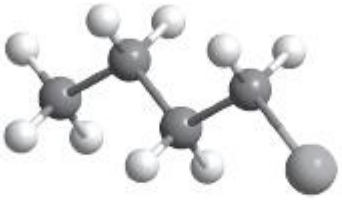
B. Propanoic acid and ethanol

C. Ethanoic acid and propan-1-ol

D. Ethanoic acid and butan-1-ol

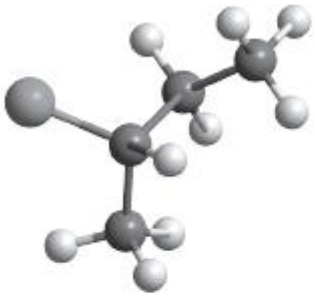
39. Which compound is optically active?

A.



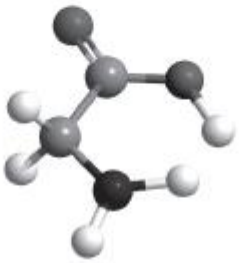
1-chlorobutane

B.



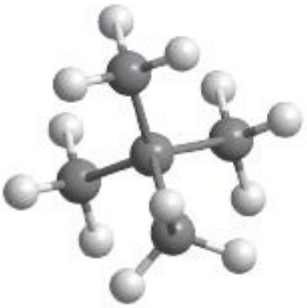
2-chlorobutane

C.



2-aminoethanoic acid

D.



2,2-dimethylpropane

Chem 10/Q# 204//**IB/Paper 1/2011/s/Time Zone 1/Higher Level/**

33. Which molecule has a chiral centre?

A. $CH_3CH{=}CHCHO$

B. $(CH_3)_2C{=}CHCH_2OH$

C. $CH_3OCH_2CH_3$

D. $CH_3CHOHCH_2CH_3$

34. The compounds $H_2NCH_2CH_2NH_2$ and $HOOCCH_2COOH$ react to form a polymer. What is the structure of the repeating unit of the polymer?

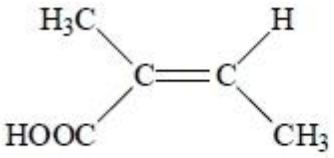
A. $\{HNCH_2CONHCH_2CH_2NHCO\}$

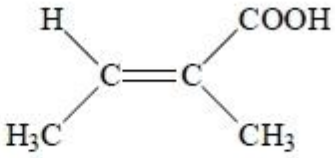
B. $\{HNCH_2CH_2NHCOCH_2CO\}$

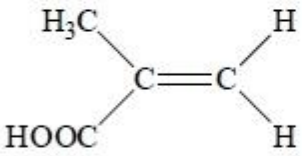
C. $\{OCCH_2CONHCH_2NHCO\}$

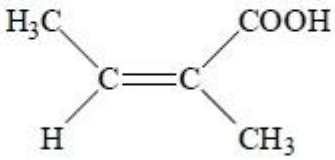
D. $\{HNCH_2CH_2NHCOCH_2NH\}$

35. Which two molecules are cis-trans isomers of each other?

W 

X 

Y 

Z 

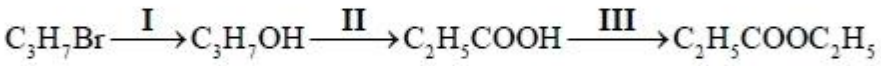
A. X and Z

B. X and Y

C. W and Y

D. W and Z

36. What is the correct order of reaction types in the following sequence?



	I	II	III
A.	substitution	oxidation	condensation
B.	addition	substitution	condensation
C.	oxidation	substitution	condensation
D.	substitution	oxidation	substitution

37. Which of the following pairs are members of the same homologous series?

A. $CH_3CH_2CH_2OH$ and CH_3CH_2CHO

B. $CH_3CH(OH)CH_3$ and $CH_3CH_2CH(OH)CH_3$

C. CH_3COCH_3 and CH_3CH_2COOH

D. $CH_3COCH_2CH_3$ and CH_3CH_2CHO

38. Which of the following statements about alkenes is **not** correct?

A. They have reactive double bonds.

B. They can form addition polymers.

C. They react mainly by substitution.

D. They can react with water to form alcohols.

39. What is the type of mechanism and an important feature of the reaction between $C(CH_3)_3Br$ and aqueous NaOH?

	Mechanism	Feature
A.	S_N1	a transition state
B.	S_N1	an intermediate
C.	S_N2	a transition state
D.	S_N2	an intermediate

34. Which of the following substances are structural isomers of each other?

I. $CH_3(CH_2)_3CH_3$

II. $(CH_3)_2CHCH_3$

III. $CH_3CH(CH_3)CH_2CH_3$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

35. Which reaction pathway describes how ethanol can be formed?

A. ethene $\xrightarrow{\text{addition}}$ chloroethane $\xrightarrow{\text{elimination}}$ ethanol

B. ethane $\xrightarrow{\text{substitution}}$ chloroethane $\xrightarrow{\text{nucleophilic substitution}}$ ethanol

C. ethene $\xrightarrow{\text{substitution}}$ ethanol

D. ethane $\xrightarrow{\text{addition}}$ ethanol

36. By which reactants and type of reaction can ethylamine (aminoethane) be produced?

	Reactants	Type of reaction
A.	$CH_3Br + NH_3$	Nucleophilic substitution
B.	$CH_3CH_2Br + NH_3$	Reduction
C.	$CH_3CN + H_2$	Nucleophilic substitution
D.	$CH_3CN + H_2$	Reduction

37. Which compound is an amide?

A. CH_3COOCH_3

B. CH_3CONH_2

C. CH_3NH_2

D. $CH_2(NH_2)COOH$

38. Which process can produce a polyester?

A. Addition polymerization of a dicarboxylic acid

B. Condensation polymerization of a diol and a dicarboxylic acid

C. Addition polymerization of a diol and dicarboxylic acid

D. Condensation polymerization of a dicarboxylic acid

39. Which statement about stereoisomers is correct?

A. 1,2-dichloroethane has two geometrical isomers.

B. 1,2-dichloroethane has two optical isomers.

C. 1,2-dichloroethene has two geometrical isomers.

D. 1,2-dichloroethene has two optical isomers.

Chem 10/Q# 206//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

33. What is the structural formula of 2,3-dibromo-3-methylhexane?

A. $CH_3CHBrCHBrCH(CH_3)CH_2CH_3$

B. $CH_3CHBrCBr(CH_3)CH_2CH_2CH_3$

C. $CH_3CH_2CHBrCBr(CH_2CH_3)_2$

D. $CH_3CHBrCHBrCH(CH_2CH_3)_2$

34. What organic product is formed in the following reaction?

$$(CH_3CH_2)CH{=}CH(CH_2CH_3) + H_2O \xrightarrow{H_2SO_4}$$

A. $CH_3(CH_2)_2CH(OH)CH_2CH_3$

B. $CH_3(CH_2)_5CH_3$

C. $CH_3(CH_2)_2CH(OSO_3H)CH_2CH_3$

D. $CH_3(CH_2)_6OH$

35. What happens when a few drops of bromine water are added to excess hex-1-ene and the mixture is shaken?

I. The colour of the bromine water disappears.

II. The organic product formed does not contain any carbon-carbon double bonds.

III. 2-bromohexane is formed.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

36. What is the IUPAC name for the following compound?

$$CH_3(CH_2)_2COOCH_3$$

A. Methyl butanoate

B. Butyl ethanoate

C. Butyl methanoate

D. Methyl propanoate

37. What is the product of the following reaction?

$$CH_3CH_2CH_2CN + 2H_2 \xrightarrow{Ni}$$

A. $CH_3CH_2CH_2NH_2$

B. $CH_3CH_2CH_2CH_2NH_2$

C. $CH_3CH_2NH_2$

D. $CH_3CH_2CH_2CH_3$

38. How many chiral carbon atoms are present in a molecule of 2,3-dibromobutane?

A. 1

B. 2

C. 3

D. 4

Chem 10/Q# 207//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

33. Which is the best definition of structural isomers?

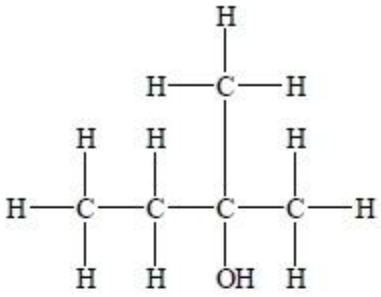
A. Compounds which have atoms with the same atomic numbers but different mass numbers

B. Compounds which have the same general formula but differ by a CH_2 group

C. Compounds which have the same empirical formula but different molecular formulas

D. Compounds which have the same molecular formula but different arrangements of atoms

34. Which is the correct classification of these alcohols?



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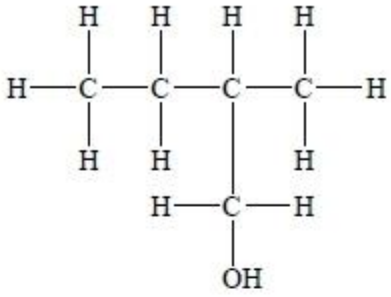

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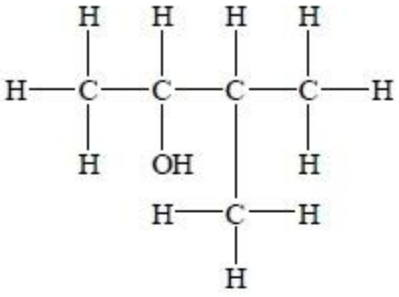


3

	1	2	3
A.	tertiary	secondary	primary
B.	tertiary	primary	secondary
C.	tertiary	tertiary	secondary
D.	secondary	primary	secondary

35. Which substances are possible products of the incomplete combustion of octane?

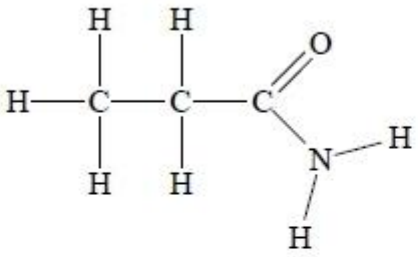
A. Carbon dioxide and hydrogen gas

B. Carbon monoxide and water vapour

C. Carbon monoxide and hydrogen gas

D. Methane and hydrogen gas

36. What is the IUPAC name of $CH_3CH_2CONH_2$?



A. Aminopropanal

B. Ethanamide

C. Propylamine

D. Propanamide

37. What is the main organic product formed from the reaction of CH_3CH_2OH with $CH_3CH_2CH_2COOH$ in the presence of an acid catalyst?

A. Ethyl butanoate

B. Butyl ethanoate

C. Ethyl propanoate

D. Propyl ethanoate

38. What are some uses of esters?

I. Flavouring agents

II. Perfumes

III. Solvents

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

39. How many isomers can exist for a compound with the molecular formula $C_2H_2Cl_2$?

A. 1

B. 2

C. 3

D. 4

Chem 10/Q# 208//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

33. How many **structural** isomers exist with the formula $C_3H_5Cl_3$?

A. 3

B. 4

C. 5

D. 6

34. Which reaction occurs via a free-radical mechanism?

A. $C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$

B. $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

C. $C_4H_9I + OH^- \rightarrow C_4H_9OH + I^-$

D. $(CH_3)_3CI + H_2O \rightarrow (CH_3)_3COH + HI$

35. Which substance is produced by the reaction of hydrogen with a vegetable oil?

A. Margarine

B. Nylon

C. Polypropene

D. Soap

36. Propene is converted to propanone in a two stage process.

$$\text{Propene} \rightarrow \text{X} \rightarrow \text{Propanone}$$

What is the formula of compound X?

A. $CH_3CHBrCH_3$

B. $CH_3CH_2CH_2Br$

C. $CH_3CHOHCH_3$

D. $CH_3CH_2CH_2OH$

37. Which compound could rotate the plane of polarization of polarized light?

A. $(CH_3)_2CHCH_2Cl$

B. $CH_3CH_2CH_2CH_2Cl$

C. $CH_3CH_2CHClCH_3$

D. $(CH_3)_3CCl$

38. What is the name of the ester formed when CH_3CH_2COOH and CH_3OH react together?

A. Ethyl methanoate

B. Methyl ethanoate

C. Propyl methanoate

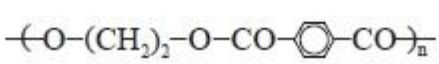
D. Methyl propanoate

39. Which formula represents a polyamide?

A. $-(-CH_2-CHCl-)_n-$

B. $-(-NH-(CH_2)_6-NH-CO-(CH_2)_4-CO-)_n-$

C. $-(-CF_2-CF_2-)_n-$

D. 

Chem 10/Q# 209//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

33. Which three compounds can be considered to be a homologous series?

A. CH_3OH, CH_3CH_2OH, $CH_3CH_2CH_2OH$

B. CH_3CH_2OH, CH_3CHO, CH_3COOH

C. $CH_3CH_2CH(OH)CH_3$, $CH_3CH_2CH_2CH_2OH$, $(CH_3)_3COH$

D. $CH_3CH_2CH_2CH_2OH$, $CH_3CH_2OCH_2CH_3$, $(CH_3)_2CH_2CHO$

34. Identify the functional group present in $HCOCH_2CH_3$.

A. Ester

B. Ketone

C. Aldehyde

D. Alcohol

35. What is the IUPAC name for $HCOOCH_2CH_2CH_3$?

A. Butanoic acid

B. Butanal

C. Methyl propanoate

D. Propyl methanoate

36. Which conditions are required to obtain a good yield of a carboxylic acid when ethanol is oxidized using potassium dichromate(VI), $K_2Cr_2O_7(aq)$?

I. Add sulfuric acid

II. Heat the reaction mixture under reflux

III. Distil the product as the oxidizing agent is added

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

37. Which statements about substitution reactions are correct?

I. The reaction between sodium hydroxide and 1-chloropentane predominantly follows an S_N2 mechanism.

II. The reaction between sodium hydroxide and 2-chloro-2-methylbutane predominantly follows an S_N2 mechanism.

III. The reaction of sodium hydroxide with 1-chloropentane occurs at a slower rate than with 1-bromopentane.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

38. What is the organic product of the reaction between methylamine and ethanoic acid?

A. CH_3COONH_4

B. $CH_3NHCOCH_3$

C. $CH_3COCH_2NH_2$

D. $CH_3CH_2CONH_2$

39. Which compound can exist as stereoisomers?

A. CH_3CH_2CHO

B. $CH_3CH_2COCH_3$

C. $CH_3CH(CH_3)_2$

D. $CH_3CH_2CHOHCH_3$

Chem 10/Q# 210//**IB/Paper 1/2008/w/Time Zone 0/Higher Level/**

36. Which of the following can form an addition polymer?

A. Alanine (2-aminopropanoic acid)

B. Butane

C. But-2-ene

D. 1,2-dichlorobutane

37. Which compound, when hydrogenated, gives a product with a chiral centre?

A. $CH_2=CH_2$

B. $CH_3CBr=CH_2$

C. $CH_3CH_2CBr=CH_2$

D. $CH_3CH_2C(CH_3)=CH_2$

38. Which statement about the reactions between halogenoalkanes and aqueous sodium hydroxide is correct?

A. The reactions involve the homolytic fission of the carbon-halogen bond.

B. Chloroalkanes react faster than iodoalkanes.

C. The reactions of primary halogenoalkanes generally involve a two-step mechanism.

D. Tertiary halogenoalkanes generally react by a S_N1 mechanism.

40. Which products are formed by the dehydration of butan-2-ol?

I. butane

II. but-1-ene

III. but-2-ene

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 10/Q# 211//**IB/Paper 1/2008/s/Time Zone 2/Higher Level/**

34. What is the coefficient for $H^+(aq)$, when this redox equation is balanced using whole numbers?

$$Cr_2O_7^{2-}(aq) + Cl^-(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + Cl_2(g) + H_2O(l)$$

A. 7

B. 2

C. 14

D. 1

35. Dilute sulfuric acid is electrolyzed using inert electrodes. What product, and in what relative amount, is produced at each electrode?

	Positive electrode	Negative electrode
A.	1 mol H_2	2 mol O_2
B.	1 mol O_2	2 mol H_2
C.	2 mol H_2	1 mol O_2
D.	2 mol O_2	1 mol H_2

36. Which molecule has a chiral carbon atom?

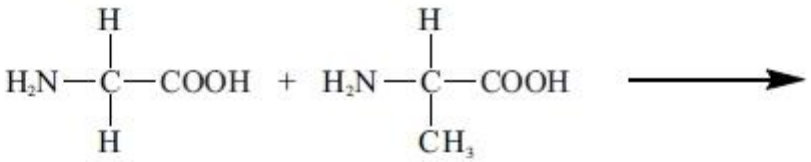
A. $CH_2CClCH_2CH_3$

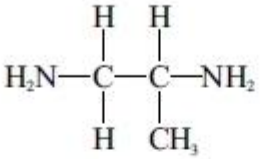
B. $CH_3CHOHCH_2CH_3$

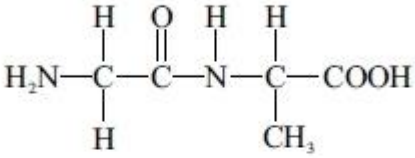
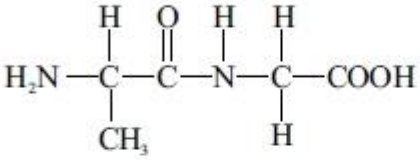
C. $(CH_3)_2CHCH_2CH_3$

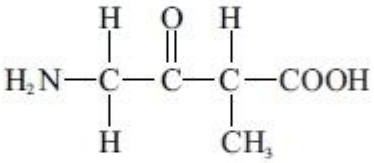
D. H_2NCH_2COOH

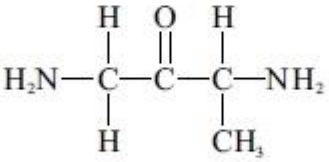
37. Which organic product(s) could form when 2-aminoethanoic acid reacts with 2-aminopropanoic acid?



A.  only

B.  and 

C.  only

D.  only

38. Which statement is correct about the determination of the structure of organic compounds?

A. Mass spectrometry is the best technique to provide information on the chemical environment of all the hydrogen atoms in a molecule.

B. ^{1}H NMR spectroscopy provides the values of carbon-hydrogen bond distances present in a molecule.

C. Infrared spectroscopy is used to determine all the bond angles and bond distances in a molecule.

D. Mass spectrometry can provide information about the relative molecular mass of a compound.

39. Which statement best describes the reaction mechanism involved in the single step conversion of chloroethane to ethanol?

A. The reaction involves removal of HCl, followed by the addition of H_2O.

B. The reaction involves heterolytic fission of the C–Cl bond, followed by a reaction with H_2O.

C. The reaction involves nucleophilic attack of OH^- in a bimolecular mechanism.

D. The reaction mechanism involves a carbocation.

40. Which statement about alcohols is correct?

A. Primary alcohols can be obtained by the reduction of carboxylic acids or aldehydes.

B. Secondary alcohols can be obtained by the oxidation of ketones.

C. Tertiary alcohols can be obtained by the reduction of carboxylic acids and ketones.

D. Alcohols can be obtained by the addition of water to alkanes, using acid as a catalyst.

Chem 10/Q# 212//**IB/Paper 1/2008/s/Time Zone 1/Higher Level/**

36. Which species **cannot** act as a nucleophile?

A. H_2O

B. NH_3

C. CN^-

D. CH_4

37. Which compounds show three main peaks in their ^1H NMR spectra?

I. $CH_3CH_2CH_2CH_3$

II. CH_3CH_2COOH

III. $(CH_3)_3CCH_2CH_2Br$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

38. Which halogenoalkane reacts most rapidly with silver nitrate solution to form a precipitate?

A. 1-bromobutane

B. 1-iodobutane

C. 2-bromo-2-methylpropane

D. 2-iodo-2-methylpropane

39. Which is the correct formula of 2,3-dichloro-2-methylpentane?

A. $CH_3CCl(CH_3)CHClCH_2CH_3$

B. $CH_3CH(CH_3)CCl_2CH_2CH_3$

C. $CH_3CCl_2CH(CH_3)CH_2CH_3$

D. $CH_3CH_2CH_2CHClCHClCH_3$

40. What type of reaction occurs when hexanedioic acid and 1,6-diaminohexane react together to form nylon?

A. Addition

B. Condensation

C. Esterification

D. Substitution

Chem 11/Q# 213//**IB/Paper 1/2014/w/Time Zone 0/Higher Level/**

40. In an experiment to determine a specific quantity, a student calculated that her experimental uncertainty was 0.9% and her experimental error was 3.5%. Which statement is correct?

A. Only random uncertainties are present in this experiment.

B. Both random uncertainties and systematic errors are present in this experiment.

C. Repeats of this experiment would reduce the systematic errors.

D. Repeats of this experiment would reduce both systematic errors and random uncertainties.

Chem 11/Q# 214//**IB/Paper 1/2014/s/Time Zone 2/Higher Level/**

40. Which statement about errors is correct?

A. A random error is always expressed as a percentage.

B. A systematic error can be reduced by taking more readings.

C. A systematic error is always expressed as a percentage.

D. A random error can be reduced by taking more readings.

Chem 11/Q# 215//**IB/Paper 1/2014/s/Time Zone 1/Higher Level/**

40. A student carries out a titration three times and obtains the following volumes: $3.0 \pm 0.1\,cm^3$, $3.2 \pm 0.1\,cm^3$ and $3.2 \pm 0.1\,cm^3$. What is the average volume?

A. $3.1 \pm 0.1\,cm^3$

B. $3.13 \pm 0.1\,cm^3$

C. $3.1 \pm 0.3\,cm^3$

D. $3.13 \pm 0.3\,cm^3$

Chem 11/Q# 216//**IB/Paper 1/2013/w/Time Zone 0/Higher Level/**

40. A student measured the mass and volume of a piece of silver and recorded the following values.

Mass of empty weighing bottle	1.0800 g
Mass of weighing bottle with piece of silver	11.5700 g
Volume of silver	$1.00\,cm^3$

Which value, in $g\,cm^{-3}$, for the density of silver should the student report in her laboratory notebook?

A. 10.49

B. 10.4900

C. 10.5

D. 10.500

Chem 11/Q# 217//**IB/Paper 1/2013/s/Time Zone 2/Higher Level/**

40. Using an accurate pH meter, the pH of lemonade was found to be 2.30. Some students deduced the pH of the lemonade after titration with a 0.10 mol dm^{-3} sodium hydroxide solution. Their determined values of pH were 2.4, 2.5, 2.4 and 2.4. What is the best description of the precision and accuracy of these measurements?

	Precision	Accuracy
A.	precise	inaccurate
B.	not precise	inaccurate
C.	precise	accurate
D.	not precise	accurate

Chem 11/Q# 218//**IB/Paper 1/2013/s/Time Zone 1/Higher Level/**

40. Which would be the best method to decrease the random uncertainty of a measurement in an acid–base titration?

A. Ensure your eye is at the same height as the meniscus when reading the burette.

B. Use a different indicator for the titration.

C. Use a different burette.

D. Repeat the titration.

Chem 11/Q# 219//**IB/Paper 1/2012/s/Time Zone 2/Higher Level/**

40. The relationship between the pressure, P, and the volume, V, of a fixed amount of gas at a constant temperature is investigated experimentally. Which statements are correct?

I. A graph of V against P will be a curve (non-linear).

II. A graph of V against $\frac{1}{P}$ will be linear.

III. $V = \text{constant} \times \frac{1}{P}$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 11/Q# 220//**IB/Paper 1/2012/s/Time Zone 1/Higher Level/**

40. A student measured the mass of a solid on an analytical balance during an internally assessed IB practical experiment and recorded the mass in his raw data. The accuracy of the balance, as stated by the manufacturers, was ± 0.01 g. Which of the following choices would be the best record of his mass?

A. 10.2 g

B. 10 g

C. 10.20 g

D. 10.200 g

Chem 11/Q# 221//**IB/Paper 1/2011/w/Time Zone 0/Higher Level/**

40. A student heated a solid in a crucible. The student measured the mass of the solid and crucible before and after heating and recorded the results.

Mass of crucible and solid before heating = 101.692 g

Mass of crucible and solid after heating = 89.312 g

What value should the student record for the mass lost in grams?

A. 12.4

B. 12.38

C. 12.380

D. 12.3800

Chem 11/Q# 222//**IB/Paper 1/2011/s/Time Zone 2/Higher Level/**

40. A piece of metallic aluminium with a mass of 10.044 g was found to have a volume of 3.70 cm^3. A student carried out the following calculation to determine the density.

$$\text{Density (g cm}^{-3}) = \frac{10.044}{3.70}$$

What is the best value the student could report for the density of aluminium?

A. 2.715 g cm^{-3}

B. 2.7 g cm^{-3}

C. 2.71 g cm^{-3}

D. 2.7146 g cm^{-3}

Chem 11/Q# 223//**IB/Paper 1/2011/s/Time Zone 1/Higher Level/**

40. A burette reading is recorded as 27.70 ± 0.05 cm^3. Which of the following could be the actual value?

I. 27.68 cm^3

II. 27.78 cm^3

III. 27.74 cm^3

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Chem 11/Q# 224//**IB/Paper 1/2010/w/Time Zone 0/Higher Level/**

40. Density can be calculated by dividing mass by volume. 0.20 ± 0.02 g of a metal has a volume of 0.050 ± 0.005 cm^3. How should its density be recorded using this data?

A. 4.0 ± 0.025 g cm^{-3}

B. 4.0 ± 0.8 g cm^{-3}

C. 4.00 ± 0.025 g cm^{-3}

D. 4.00 ± 0.8 g cm^{-3}

Chem 11/Q# 225//**IB/Paper 1/2010/s/Time Zone 2/Higher Level/**

39. How many significant figures are there in 0.00370?

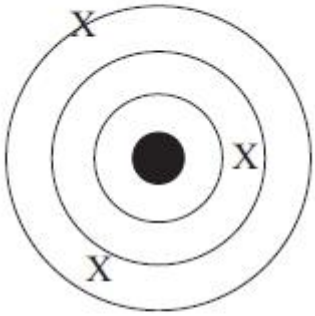
A. 2

B. 3

C. 5

D. 6

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.

Chem 11/Q# 226//**IB/Paper 1/2010/s/Time Zone 1/Higher Level/**

40. Which experimental procedure is most likely to lead to a large systematic error?

A. Determining the concentration of an alkali by titration with a burette

B. Measuring the volume of a solution using a volumetric pipette

C. Determining the enthalpy change of neutralization in a beaker

D. Measuring the volume of a gas produced with a gas syringe

Chem 11/Q# 227//**IB/Paper 1/2009/w/Time Zone 0/Higher Level/**

40. Which are likely to be reduced when an experiment is repeated a number of times?

A. Random errors

B. Systematic errors

C. Both random and systematic errors

D. Neither random nor systematic errors

Chem 11/Q# 228//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

40. Which would be the best method to decrease the **random** uncertainty of a measurement in an acid-base titration?

A. Repeat the titration

B. Ensure your eye is at the same height as the meniscus when reading from the burette

C. Use a different burette

D. Use a different indicator for the titration

Chem 11/Q# 229//**IB/Paper 1/2009/s/Time Zone 2/Higher Level/**

33. What structural feature must a molecule have in order to undergo addition polymerization?

A. Two functional groups

B. A carbon–carbon double bond

C. Carbon atoms singly bonded together

D. A polar covalent bond

34. What is the product of the oxidation of butan-2-ol?

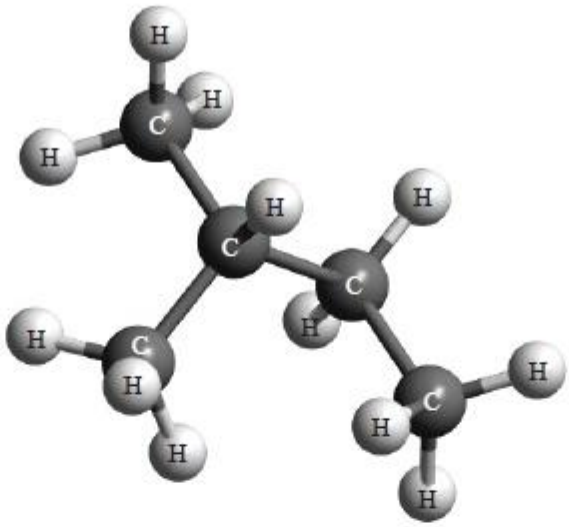
A. But-2-ene

B. Butanoic acid

C. Butanal

D. Butanone

35. What is the IUPAC name of the following compound?



A. 2-methylbutane

B. Ethylpropane

C. 3-methylbutane

D. Pentane

36. Which equations represent the incomplete combustion of methane?

I. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

II. $CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(g)$

III. $CH_4(g) + O_2(g) \rightarrow C(s) + 2H_2O(g)$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

37. What is the organic product of the reaction between $CH_3CH_2NH_2$ and CH_3CH_2COOH?

A. $CH_3CH_2NHCOCH_2CH_3$

B. $CH_3CH_2CH_2NHCOCH_3$

C. $CH_3CH_2NHCOCH_3$

D. $CH_3NHCOCH_3$

38. What is the IUPAC name of the compound $CH_3CH_2COOCH_2CH_3$?

A. Ethyl ethanoate

B. Propyl ethanoate

C. Ethyl propanoate

D. Pentyl propanoate

39. Which statement is correct about the enantiomers of a chiral compound?

A. Their physical properties are different.

B. All their chemical reactions are identical.

C. A racemic mixture will rotate the plane of polarized light.

D. They will rotate the plane of polarized light in opposite directions.

Chem 11/Q# 230//**IB/Paper 1/2009/s/Time Zone 1/Higher Level/**

40. A student recorded the volume of a gas as 0.01450 dm^3. How many significant figures are there in this value?

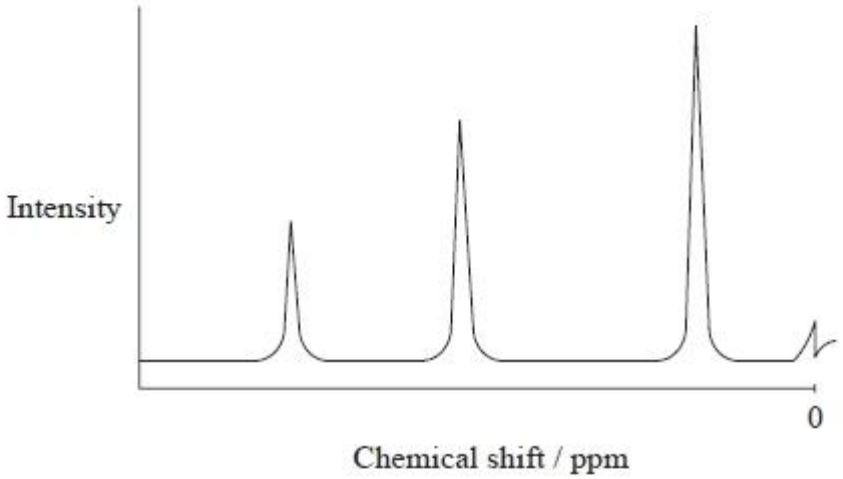
A. 3

B. 4

C. 5

D. 6

39. An unknown organic compound gives the ^1H low resolution nuclear magnetic spectrum below. The peak at 0 ppm is due to the TMS reference.



Identify the organic compound.

A. $CH_3CH_2CH_3$

B. CH_2OHCH_2OH

C. CH_3CH_2OH

D. CH_3CH_2Cl

Mark Scheme – Topic 1

Q# 1/ IB/Paper 1/2014/w/TZ0/HL

1. D
2. B
3. D

Q# 2/ IB/Paper 1/2014/s/TZ2/HL

1. D
2. C
3. B

Q# 3/ IB/Paper 1/2014/s/TZ1/HL

1. B
2. D
3. A

Q# 4/ IB/Paper 1/2013/w/TZ0/HL

1. D
2. D
3. B

Q# 5/ IB/Paper 1/2013/s/TZ2/HL

1. C
2. B
3. B

Q# 6/ IB/Paper 1/2013/s/TZ1/HL

1. C
2. D
3. D

Q# 7/ IB/Paper 1/2012/w/TZ0/HL

1. C
2. B
3. A

Q# 8/ IB/Paper 1/2012/s/TZ2/HL

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

Q# 9/ IB/Paper 1/2012/s/TZ1/HL

1. D
2. A
3. B

Q# 10/ IB/Paper 1/2011/w/TZ0/HL

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

Q# 11/ IB/Paper 1/2011/s/TZ2/HL

1. D
2. A
3. C

Q# 12/ IB/Paper 1/2011/s/TZ1/HL

1. B
2. D
3. D
4. D

Q# 13/ IB/Paper 1/2010/w/TZ0/HL

1. D
2. C
3. C

Q# 14/ IB/Paper 1/2010/s/TZ2/HL

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

Q# 15/ IB/Paper 1/2010/s/TZ1/HL

1. D
2. A
3. A

Q# 16/ IB/Paper 1/2009/w/TZ0/HL

1. C
2. D
3. D
4. C

Q# 17/ IB/Paper 1/2009/s/TZ2/HL

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

Q# 18/ IB/Paper 1/2009/s/TZ1/HL

1. A
2. B
3. B

Q# 19/ IB/Paper 1/2008/w/TZ0/HL

1. B
2. C
3. D

Q# 20/ IB/Paper 1/2008/s/TZ2/HL

1. C
2. D
3. C

Q# 21/ IB/Paper 1/2008/s/TZ1/HL

15. A

Q# 22/ IB/Paper 1/2008/s/TZ1/HL

1. D

2. C

3. B

Q# 23/ IB/Paper 1/2014/w/TZ0/HL

4. B

Q# 24/ IB/Paper 1/2014/s/TZ2/HL

4. A

5. B

Topic 2 MS

Q# 25/ IB/Paper 1/2014/s/TZ1/HL

4. B

5. C

Q# 26/ IB/Paper 1/2013/w/TZ0/HL

4. B

5. D

Q# 27/ IB/Paper 1/2013/s/TZ2/HL

5. B

6. B

Q# 28/ IB/Paper 1/2013/s/TZ1/HL

4. B

5. C

Q# 29/ IB/Paper 1/2012/s/TZ2/HL

5. A

6. B

Q# 30/ IB/Paper 1/2012/s/TZ1/HL

4. C

5. C

6. B

7. D

8. D

Q# 31/ IB/Paper 1/2011/w/TZ0/HL

6. D

Q# 32/ IB/Paper 1/2011/s/TZ2/HL

4. C

5. B

Q# 33/ IB/Paper 1/2011/s/TZ1/HL

5. B

6. B

Q# 34/ IB/Paper 1/2010/w/TZ0/HL

4. A

Q# 35/ IB/Paper 1/2010/s/TZ2/HL

5. B

Q# 36/ IB/Paper 1/2010/s/TZ1/HL

4. D

5. B

6. B

Q# 37/ IB/Paper 1/2009/s/TZ2/HL

5. D

6. B

7. D

Q# 38/ IB/Paper 1/2009/s/TZ1/HL

4. A

5. C

Q# 39/ IB/Paper 1/2008/w/TZ0/HL

6. C

Q# 40/ IB/Paper 1/2008/s/TZ2/HL

4. D

12. C

Q# 41/ IB/Paper 1/2008/s/TZ1/HL

4. D

5. C

Q# 42/ IB/Paper 1/2014/w/TZ0/HL

5. B

6. A

7. D

8. B

Topic 3 MS

Q# 43/ IB/Paper 1/2014/s/TZ2/HL

4. A

5. B

6. B

7. C

Q# 44/ IB/Paper 1/2014/s/TZ1/HL

6. C

7. B

Q# 45/ IB/Paper 1/2013/w/TZ0/HL

6. C

7. A

8. A

9. A

Q# 46/ IB/Paper 1/2013/s/TZ2/HL

7. C

8. A

Q# 47/ IB/Paper 1/2013/s/TZ1/HL

6. A

7. B

8. C

9. A

Q# 48/ IB/Paper 1/2012/w/TZ0/HL

5. A

6. B

7. D

8. B

Q# 49/ IB/Paper 1/2012/s/TZ2/HL

7. B

8. C

Q# 50/ IB/Paper 1/2012/s/TZ1/HL

6. B

Q# 51/ IB/Paper 1/2012/s/TZ1/HL

7. D

Q# 52/ IB/Paper 1/2011/w/TZ0/HL

7. C

8. A

9. B

Q# 53/ IB/Paper 1/2011/s/TZ2/HL

6. A

7. A

8. D

9. B

Q# 54/ IB/Paper 1/2011/s/TZ1/HL

7. C

8. C

9. D

Q# 55/ IB/Paper 1/2010/w/TZ0/HL

5. B

6. A

7. A

8. D

9. D

Q# 56/ IB/Paper 1/2010/s/TZ2/HL

6. C

7. B

8. A

Q# 57/ IB/Paper 1/2010/s/TZ1/HL

7. C

8. A

9. D

Q# 58/ IB/Paper 1/2009/w/TZ0/HL

6. C

7. D

8. B

9. C

Q# 59/ IB/Paper 1/2009/s/TZ2/HL

8. B

9. C

10. C

Q# 60/ IB/Paper 1/2009/s/TZ1/HL

6. B

7. B

8. C

Q# 61/ IB/Paper 1/2008/w/TZ0/HL

4. D

Q# 62/ IB/Paper 1/2008/w/TZ0/HL

6. C

7. C

8. B

9. A

Q# 63/ IB/Paper 1/2008/w/TZ0/HL

11. B

12. D

13. C

14. B

15. B

Q# 64/ IB/Paper 1/2008/s/TZ2/HL

5. D

7. C

8. A

9. B

11. B

Q# 65/ IB/Paper 1/2008/s/TZ1/HL

7. C

8. B

9. A

10. C

Topic 4 MS

Q# 66/ IB/Paper 1/2014/w/TZ0/HL

9. D

10. B

11. D

12. C

13. C

Q# 67/ IB/Paper 1/2014/s/TZ2/HL

9. C

10. D

11. C

12. C

13. A

Q# 68/ IB/Paper 1/2014/s/TZ1/HL

8. A

9. D

10. D

Q# 69/ IB/Paper 1/2014/s/TZ1/HL

10. D

11. C

12. C

13. B

14. B

Q# 70/ IB/Paper 1/2013/w/TZ0/HL

10. C

11. A

12. A

13. C

14. A

Q# 71/ IB/Paper 1/2013/s/TZ2/HL

25. D

Q# 72/ IB/Paper 1/2013/s/TZ2/HL

9. C

10. A

11. D

12. C

13. C

Q# 73/ IB/Paper 1/2013/s/TZ1/HL

10. C

Q# 74/ IB/Paper 1/2013/s/TZ1/HL

11. A

12. D

13. B

Q# 75/ IB/Paper 1/2012/w/TZ0/HL

9. A

10. D

11. C

12. B

13. C

Q# 76/ IB/Paper 1/2012/s/TZ2/HL

9. B

10. D

11. A

12. A

13. D

14. C

Q# 77/ IB/Paper 1/2012/s/TZ1/HL

9. B

10. D

11. A

12. C

13. B

Q# 78/ IB/Paper 1/2011/s/TZ2/HL

10. C

11. B

12. C

13. C

14. D

15. A

Q# 79/ IB/Paper 1/2011/s/TZ1/HL

10. B

11. A

12. A

13. C

14. A

Q# 80/ IB/Paper 1/2010/w/TZ0/HL

9. D

10. C

11. D

12. A

13. A

14. A

Q# 81/ IB/Paper 1/2010/s/TZ2/HL

9. B

10. B

11. A

12. D

13. D

Q# 82/ IB/Paper 1/2010/s/TZ1/HL

10. D

11. A

12. B

13. B

14. C

Q# 83/ IB/Paper 1/2009/w/TZ0/HL

10. D

11. B

12. B

13. B

14. A

Q# 84/ IB/Paper 1/2009/s/TZ2/HL

11. D
12. A
13. C
14. A
15. A

Q# 85/ IB/Paper 1/2009/s/TZ1/HL

9. D
10. D
11. D
12. A
13. A

Q# 86/ IB/Paper 1/2008/s/TZ2/HL

13. D
14. D
15. C

Q# 87/ IB/Paper 1/2008/s/TZ1/HL

11. C
12. B
13. B
14. C

Topic 5 MS

Q# 88/ IB/Paper 1/2014/w/TZ0/HL

14. A
15. C
16. B
17. C
18. D

Q# 89/ IB/Paper 1/2014/s/TZ2/HL

14. B
15. A
16. B
17. A
18. D
19. A

Q# 90/ IB/Paper 1/2014/s/TZ1/HL

14. B
15. D
16. A
17. C
18. B

Q# 91/ IB/Paper 1/2013/w/TZ0/HL

15. B
16. A
17. D
18. C
19. D

Q# 92/ IB/Paper 1/2013/s/TZ2/HL

14. A
15. A
16. B
17. A
18. C

Q# 93/ IB/Paper 1/2013/s/TZ1/HL

14. A
15. B
16. A
17. A
18. B

Q# 94/ IB/Paper 1/2012/w/TZ0/HL

14. D
15. B
16. D
17. D
18. A
19. B

Q# 95/ IB/Paper 1/2012/s/TZ1/HL

14. D
15. D
16. A
17. C
18. B

Q# 96/ IB/Paper 1/2011/w/TZ0/HL

10. C
11. A
12. A
13. C
14. A

Q# 97/ IB/Paper 1/2011/w/TZ0/HL

15. A
16. C
17. B
18. A

Q# 98/ IB/Paper 1/2011/s/TZ2/HL

16. A
17. A
18. D
19. D

Q# 99/ IB/Paper 1/2011/s/TZ1/HL

15. B
16. C
17. A

18. A

19. D

Q# 100/ IB/Paper 1/2010/w/TZ0/HL

15. C

16. A

17. D

18. C

Q# 101/ IB/Paper 1/2010/s/TZ2/HL

14. C

15. B

16. A

17. B

19. A

20. A

Q# 102/ IB/Paper 1/2010/s/TZ1/HL

15. B

16. C

17. A

18. C

Q# 103/ IB/Paper 1/2009/w/TZ0/HL

15. D

16. C

17. C

18. D

Q# 104/ IB/Paper 1/2009/s/TZ2/HL

16. B

17. D

18. B

19. A

Q# 105/ IB/Paper 1/2009/s/TZ1/HL

14. C

15. B

16. A

17. A

18. B

Q# 106/ IB/Paper 1/2008/w/TZ0/HL

16. C

17. D

18. A

19. C

20. A

21. A

Q# 107/ IB/Paper 1/2008/s/TZ2/HL

16. D

17. A

18. D

19. C

20. A

21. C

Q# 108/ IB/Paper 1/2008/s/TZ1/HL

16. B

17. A

18. C

19. B

20. B

21. C

Topic 6 MS

Q# 109/ IB/Paper 1/2014/w/TZ0/HL

19. B

20. C

21. D

Q# 110/ IB/Paper 1/2014/s/TZ2/HL

20. C

21. D

22. C

23. D

Q# 111/ IB/Paper 1/2014/s/TZ1/HL

19. C

20. C

21. C

Q# 112/ IB/Paper 1/2013/w/TZ0/HL

20. A

21. C

22. D

Q# 113/ IB/Paper 1/2013/s/TZ2/HL

19. A

20. C

21. D

22. B

Q# 114/ IB/Paper 1/2013/s/TZ1/HL

19. D

20. A

21. B

Q# 115/ IB/Paper 1/2012/w/TZ0/HL

19. B

20. D

21. C

Q# 116/ IB/Paper 1/2012/s/TZ2/HL

15. D

16. A

17. C

18. A

19. A

20. D

Q# 117/ IB/Paper 1/2012/s/TZ1/HL

19. A

20. A

21. B

22. A

Q# 118/ IB/Paper 1/2011/w/TZ0/HL

19. B

20. C

21. C

22. A

Q# 119/ IB/Paper 1/2011/s/TZ2/HL

20. D

21. C

22. A

Q# 120/ IB/Paper 1/2011/s/TZ1/HL

20. B

21. C

22. A

23. C

Q# 121/ IB/Paper 1/2010/w/TZ0/HL

19. A

20. C

21. B

Q# 122/ IB/Paper 1/2010/s/TZ2/HL

18. C

21. D

22. D

Q# 123/ IB/Paper 1/2010/s/TZ1/HL

19. C

20. C

21. B

22. D

Q# 124/ IB/Paper 1/2009/w/TZ0/HL

19. B

20. C

21. D

Q# 125/ IB/Paper 1/2009/s/TZ2/HL

20. C

21. B

22. C

Q# 126/ IB/Paper 1/2009/s/TZ1/HL

19. D

20. D

21. C

22. C

23. C

Q# 127/ IB/Paper 1/2008/w/TZ0/HL

22. C

23. D

24. B

Q# 128/ IB/Paper 1/2008/s/TZ2/HL

22. A

23. B

24. B

25. D

Q# 129/ IB/Paper 1/2008/s/TZ1/HL

22. C

23. D

24. D

25. B

Topic 7 MS

Q# 130/ IB/Paper 1/2014/w/TZ0/HL

22. B

23. A

Q# 131/ IB/Paper 1/2014/s/TZ2/HL

8. B

Q# 132/ IB/Paper 1/2014/s/TZ2/HL

23. D

Q# 133/ IB/Paper 1/2014/s/TZ1/HL

22. A

Q# 134/ IB/Paper 1/2013/w/TZ0/HL

23. D

Q# 135/ IB/Paper 1/2013/s/TZ2/HL

23. D

Q# 136/ IB/Paper 1/2013/s/TZ1/HL

22. B

23. A

Q# 137/ IB/Paper 1/2012/w/TZ0/HL

22. A

23. A

Q# 138/ IB/Paper 1/2012/s/TZ2/HL

21. D

Q# 139/ IB/Paper 1/2011/w/TZ0/HL

23. B

Q# 140/ IB/Paper 1/2011/s/TZ2/HL

23. D

Q# 141/ IB/Paper 1/2011/s/TZ1/HL

24. C

Q# 142/ IB/Paper 1/2010/w/TZ0/HL

22. D

Q# 143/ IB/Paper 1/2010/s/TZ2/HL

23. D

Q# 144/ IB/Paper 1/2010/s/TZ1/HL

23. D

Q# 145/ IB/Paper 1/2009/w/TZ0/HL

22. C

Q# 146/ IB/Paper 1/2009/s/TZ1/HL

24. D

Q# 147/ IB/Paper 1/2008/w/TZ0/HL

25. C

Q# 148/ IB/Paper 1/2008/w/TZ0/HL

27. D

Q# 149/ IB/Paper 1/2008/s/TZ1/HL

25. B

Topic 8 MS

Q# 150/ IB/Paper 1/2014/w/TZ0/HL

24. D

25. C

26. C

27. A

28. A

29. B

Q# 151/ IB/Paper 1/2014/s/TZ2/HL

25. C

26. C

27. B

28. D

29. A

30. B

Q# 152/ IB/Paper 1/2014/s/TZ1/HL

24. D

25. C

26. A

27. A

28. B

29. B

Q# 153/ IB/Paper 1/2013/w/TZ0/HL

25. C

26. B

27. B

28. A

29. D

30. A

Q# 154/ IB/Paper 1/2013/s/TZ2/HL

26. B

27. C

28. C

29. D

Q# 155/ IB/Paper 1/2013/s/TZ1/HL

24. D

25. C

26. C

27. B

28. D

29. A

Q# 156/ IB/Paper 1/2012/w/TZ0/HL

24. C

25. A

26. B

27. A

28. A

29. D

Q# 157/ IB/Paper 1/2012/s/TZ2/HL

23. D

24. B

25. D

26. C

27. C

Q# 158/ IB/Paper 1/2012/s/TZ1/HL

24. A

25. B

26. A

27. D

28. D

29. A

Q# 159/ IB/Paper 1/2011/w/TZ0/HL

25. B

26. D

27. B

28. C

29. C

Q# 160/ IB/Paper 1/2011/s/TZ2/HL

25. C
26. A
27. A
28. B
29. C

Q# 161/ IB/Paper 1/2011/s/TZ1/HL

26. C
27. C
28. D
29. D

Q# 162/ IB/Paper 1/2010/w/TZ0/HL

24. B
25. C
26. A
27. C
28. C
29. C

Q# 163/ IB/Paper 1/2010/s/TZ2/HL

24. D
25. A
26. C
27. C
28. A
29. C

Q# 164/ IB/Paper 1/2010/s/TZ1/HL

25. D
26. C
27. B
28. A
29. A

Q# 165/ IB/Paper 1/2009/w/TZ0/HL

24. D
25. B
26. C
27. C
28. A

Q# 166/ IB/Paper 1/2009/s/TZ2/HL

24. D
25. A
26. C
27. D
28. A
29. B

Q# 167/ IB/Paper 1/2009/s/TZ1/HL

26. B
27. D
28. C
29. C

Q# 168/ IB/Paper 1/2008/w/TZ0/HL

28. B
29. D
30. D
31. B

Q# 169/ IB/Paper 1/2008/s/TZ2/HL

27. A
28. B
29. C
30. C
31. A

Q# 170/ IB/Paper 1/2008/s/TZ1/HL

26. B
27. B
28. D
29. C
30. D

Topic 9 MS

Q# 171/ IB/Paper 1/2014/w/TZ0/HL

30. A
31. D
32. C
33. C

Q# 172/ IB/Paper 1/2014/s/TZ2/HL

31. D
32. A
33. A
34. B

Q# 173/ IB/Paper 1/2014/s/TZ1/HL

30. A
31. D
32. D
33. C

Q# 174/ IB/Paper 1/2013/w/TZ0/HL

31. C

32. C

33. B

34. D

Q# 175/ IB/Paper 1/2013/s/TZ2/HL

30. B

31. D

32. A

Q# 176/ IB/Paper 1/2013/s/TZ1/HLf

30. C

31. A

32. A

33. D

Q# 177/ IB/Paper 1/2012/w/TZ0/HL

30. B

31. D

32. C

33. C

Q# 178/ IB/Paper 1/2012/s/TZ2/HL

28. B

29. C

30. D

31. C

Q# 179/ IB/Paper 1/2012/s/TZ1/HL

30. C

31. B

32. C

33. D

Q# 180/ IB/Paper 1/2011/w/TZ0/HL

30. D

31. B

32. B

Q# 181/ IB/Paper 1/2011/s/TZ2/HL

30. C

31. B

32. D

33. B

Q# 182/ IB/Paper 1/2011/s/TZ1/HL

30. A

31. B

32. B

Q# 183/ IB/Paper 1/2010/w/TZ0/HL

30. C

31. B

32. A

33. C

Q# 184/ IB/Paper 1/2010/s/TZ2/HL

30. A

31. A

32. D

Q# 185/ IB/Paper 1/2010/s/TZ1/HL

30. B

31. D

32. C

33. D

Q# 186/ IB/Paper 1/2009/w/TZ0/HL

29. D

30. D

31. A

32. B

Q# 187/ IB/Paper 1/2009/s/TZ2/HL

30. B

31. B

32. C

Q# 188/ IB/Paper 1/2009/s/TZ1/HL

30. A

31. B

32. B

Q# 189/ IB/Paper 1/2008/w/TZ0/HL

32. B

33. D

34. B

35. A

Q# 190/ IB/Paper 1/2008/s/TZ2/HL

31. A

32. D

33. A

34. C

35. B

Q# 191/ IB/Paper 1/2008/s/TZ1/HL

31. B

32. C

33. B

34. D

35. A

Topic 10 MS

Q# 192/ IB/Paper 1/2014/w/TZ0/HL

34. C

35. B

36. D

37. D

38. D

39. A

Q# 193/ IB/Paper 1/2014/s/TZ2/HL

35. B
36. D
37. D
38. C
39. A

Q# 194/ IB/Paper 1/2014/s/TZ1/HL

34. B
35. C
36. A
37. A
38. B
39. D

Q# 195/ IB/Paper 1/2013/w/TZ0/HL

35. B
36. C
37. B
38. B
39. B

Q# 196/ IB/Paper 1/2013/s/TZ2/HL

33. C
34. A
35. D
36. D
37. D
38. A
39. A

Q# 197/ IB/Paper 1/2013/s/TZ1/HL

34. C
35. D
36. C
37. D
38. B
39. C

Q# 198/ IB/Paper 1/2012/w/TZ0/HL

40. C

Q# 199/ IB/Paper 1/2012/w/TZ0/HL

34. C
35. C
36. B
37. D
38. A
39. B

Q# 200/ IB/Paper 1/2012/s/TZ2/HL

32. B
33. A
34. D
35. B
36. B
37. A
38. B
39. C

Q# 201/ IB/Paper 1/2012/s/TZ1/HL

34. B
35. D
36. D
37. C
38. A
39. D

Q# 202/ IB/Paper 1/2011/w/TZ0/HL

33. B
34. C
35. A
36. D
37. D
38. D
39. D

Q# 203/ IB/Paper 1/2011/s/TZ2/HL

34. D
35. C
36. B
37. C
38. A
39. B

Q# 204/ IB/Paper 1/2011/s/TZ1/HL

33. D

34. B

35. A

36. A

37. B

38. C

39. B

Q# 205/ IB/Paper 1/2010/w/TZ0/HL

34. B

35. B

36. D

37. B

38. B

39. C

Q# 206/ IB/Paper 1/2010/s/TZ2/HL

33. B

34. A

35. A

36. A

37. B

38. B

Q# 207/ IB/Paper 1/2010/s/TZ1/HL

33. D

34. B

35. B

36. D

37. A

38. D

39. C

Q# 208/ IB/Paper 1/2009/w/TZ0/HL

33. C

34. A

35. A

36. C

37. C

38. D

39. B

Q# 209/ IB/Paper 1/2009/s/TZ1/HL

33. A

34. C

35. D

36. A

37. B

38. B

39. D

Q# 210/ IB/Paper 1/2008/w/TZ0/HL

36. C

37. C

38. D

40. C

Q# 211/ IB/Paper 1/2008/s/TZ2/HL

34. C

35. B

36. B

37. B

38. D

39. C

40. A

Q# 212/ IB/Paper 1/2008/s/TZ1/HL

36. D

37. C

38. D

39. A

40. B

Topic 11 MS

Q# 213/ IB/Paper 1/2014/w/TZ0/HL

40. B

Q# 214/ IB/Paper 1/2014/s/TZ2/HL

40. D

Q# 215/ IB/Paper 1/2014/s/TZ1/HL

40. A

Q# 216/ IB/Paper 1/2013/w/TZ0/HL

40. C

Q# 217/ IB/Paper 1/2013/s/TZ2/HL

40. B

Q# 218/ IB/Paper 1/2013/s/TZ1/HL

40. D

Q# 219/ IB/Paper 1/2012/s/TZ2/HL

40. D

Q# 220/ IB/Paper 1/2012/s/TZ1/HL

40. C

Q# 221/ IB/Paper 1/2011/w/TZ0/HL

40. C

Q# 222/ IB/Paper 1/2011/s/TZ2/HL

40. C

Q# 223/ IB/Paper 1/2011/s/TZ1/HL

40. B

Q# 224/ IB/Paper 1/2010/w/TZ0/HL

40. B

Q# 225/ IB/Paper 1/2010/s/TZ2/HL

39. B

40. A

Q# 226/ IB/Paper 1/2010/s/TZ1/HL

40. C

Q# 227/ IB/Paper 1/2009/w/TZ0/HL

40. A

Q# 228/ IB/Paper 1/2009/s/TZ2/HL

40. A

Q# 229/ IB/Paper 1/2009/s/TZ2/HL

33. B

34. D

35. A

36. C

37. A

38. C

39. D

Q# 230/ IB/Paper 1/2009/s/TZ1/HL

40. B

Q# 231/ IB/Paper 1/2008/w/TZ0/HL

39. C