

**Dunman High School**  
**2017 Year 6 H1 Chemistry (8872) Preliminary Examination**  
**Paper 2**

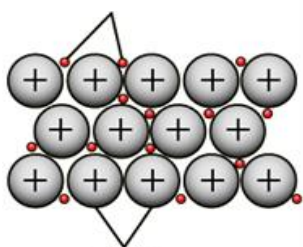
**Section A**

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

- 1 (a) (i) Average titre value =  $(10.05 + 9.95) / 2$   
 $= 10.00 \text{ cm}^3$
- (ii) Amount of nitric acid =  $(10.0/1000) / 1 = 0.01 \text{ mol}$   
 Since  $\text{VO}_2^+ \equiv \text{V}^{2+}$ ,  
 Amount of  $\text{V}^{2+}$  in  $25.0 \text{ cm}^3 = 25/250 \times 0.60 \times 250/1000$   
 $= 0.015 \text{ mol}$   
 Mole ratio of  $\text{V}^{2+} : \text{NO}_3^- = 0.015 : 0.01$   
 $= 3 : 2$
- (iii) Let final oxidation state of vanadium be  $x$ .  
 $\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$   
 $\text{V}^{2+} \rightarrow \text{V}^{x+} + (x - 2)\text{e}^-$   
 Since  $\text{V}^{2+} : \text{NO}_3^- = 3 : 2$ ,  
 $6 = 3(x - 2)$   
 $x = +4$   
 Final oxidation product:  $\text{VO}^{2+}$   
 Colour of solution: Blue
- (iv)  $\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$   
 $3\text{V}^{2+} + 2\text{NO}_3^- + 2\text{H}^+ \rightarrow 3\text{VO}^{2+} + 2\text{NO} + \text{H}_2\text{O}$

(b)

delocalised electrons

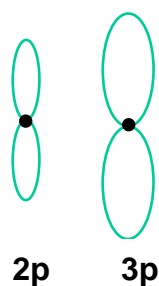


vanadium ions

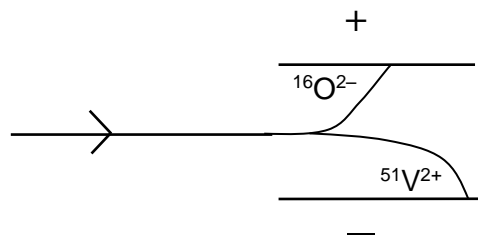
Metallic bonding is present in vanadium where there is electrostatic forces of attraction between vanadium ions and the delocalised sea of electrons.

- (c) (i)  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$

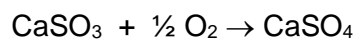
(ii)

(iii)  $-15.9^\circ$ 

(iv)



2 (a) (i) Combustion of coal.

(ii)  $\text{H}_2\text{O}(\text{g})$  or water vapour.(iii)  $\text{NO}_x$  is likely formed from reaction of oxygen and nitrogen in the air at high temperatures during combustion of coal.(b)  $\text{SO}_2 + \text{CaCO}_3 \rightarrow \text{CaSO}_3 + \text{CO}_2$ (c) Mass of  $\text{SO}_2$  that could be removed in FGD plant depends on mass of  $\text{CaCO}_3$  used.

$$\text{Moles of CaCO}_3 \text{ used} = 2.5 \times 10^5 \times 10^6 / 100.1 = 2.4975 \times 10^9 \text{ mol}$$

$$\text{Maximum moles of SO}_2 \text{ can be removed} = \text{Moles of CaCO}_3 \text{ used}$$

$$\begin{aligned} \text{Maximum mass of SO}_2 &= 2.4975 \times 10^9 \times 64.1 \\ &= 1.60 \times 10^{11} \text{ g or } 1.60 \times 10^8 \text{ kg or } 1.60 \times 10^5 \text{ t} \end{aligned}$$

(d)

$$\begin{aligned} \text{Mass of SO}_2 \text{ in flue gases 5 year} &= (1.6009 \times 10^{11} \text{ g} \times 0.10/0.90) \times 5 \\ &= 8.89 \times 10^{10} \text{ g or } 8.89 \times 10^7 \text{ kg or } 8.89 \times 10^4 \text{ t} \end{aligned}$$

(e) Magnesium oxide is basic and can undergo acid-base reaction with (acidic) sulfur dioxide.

(f) (i)

oxides	$\left  \frac{q_+ q_-}{r_+ + r_-} \right $
MgO	19.5
Na <sub>2</sub> O	8.5
CaO	16.7

(ii)  $\left| \frac{q_+ q_-}{r_+ + r_-} \right| : \text{MgO} > \text{CaO} > \text{Na}_2\text{O}$ Magnitude of lattice energy (given by  $\left| \frac{q_+ q_-}{r_+ + r_-} \right|$ ) : MgO > CaO > Na<sub>2</sub>OIonic bond strength of metal oxides: MgO > CaO > Na<sub>2</sub>OAmount of energy to overcome ionic bonds in oxide: MgO > CaO > Na<sub>2</sub>O $\therefore$  melting point: MgO > CaO > Na<sub>2</sub>O

(iii)

oxides	pH of resulting solution
MgO	9
Na <sub>2</sub> O	13
CaO	10 pH of MgO < pH < pH of Na <sub>2</sub> O

CaO has a less exothermic/ lower magnitude of lattice energy than MgO. Thus, CaO should be more soluble than MgO and so giving a higher concentration of OH<sup>-</sup> ions when oxide is added to water. pH of the resulting solution of CaO is between that of Na<sub>2</sub>O and MgO.

(g) When SO<sub>2</sub> is absorbed in the water, it will react with water and oxygen to form sulfate and H<sup>+</sup> ions. The presence of HCO<sub>3</sub><sup>-</sup> in the seawater will remove H<sup>+</sup> ions, causing a decrease in [H<sup>+</sup>]. This will shift the position of equilibrium (1) to the right, removing SO<sub>2</sub>.

OR

When SO<sub>2</sub> is absorbed in the water, it will react with water and oxygen to form sulfate and H<sup>+</sup> ions. The presence of HCO<sub>3</sub><sup>-</sup> in the seawater will remove H<sup>+</sup> ions as CO<sub>2</sub>, which will escape into the atmosphere. This will shift the position of equilibrium (2) forward, which in turn shifts the position of equilibrium (1) to the right, removing SO<sub>2</sub>.

3 (a) (i)

	2SO <sub>2</sub> (g)	+	O <sub>2</sub> (g)	⇌	2SO <sub>3</sub> (g)
initial moles / mol	69.2		34.6		0
change in moles / mol	- 65.6		- 32.8		+ 65.6
moles at eqm / mol	3.6		1.8		65.6
conc at eqm / mol dm <sup>-3</sup>	1.8		0.9		32.8

$$\begin{aligned}
 K_c &= \frac{[SO_3]^2}{[SO_2]^2[O_2]} \\
 &= \frac{(32.8)^2}{(1.8)^2(0.9)} \\
 &= 368.94 \\
 &= 369 \text{ mol}^{-1} \text{ dm}^3
 \end{aligned}$$

(ii)

For 99% SO<sub>2</sub> to be converted to SO<sub>3</sub>, it means that 1% SO<sub>2</sub> remains.

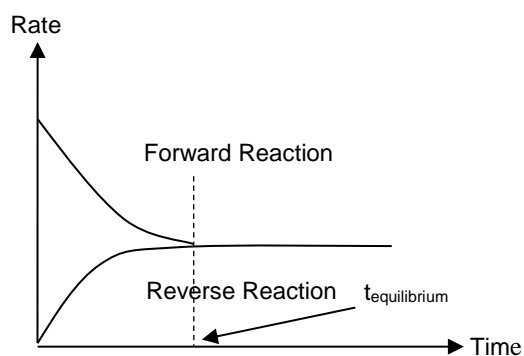
$$\frac{[SO_3]}{[SO_2]} = \frac{99}{1}$$

$$\begin{aligned}
 \text{Hence, } K_c = 368.94 &= \left(\frac{99}{1}\right)^2 \frac{1}{[O_2]} \\
 [O_2] &= 26.565 \\
 &= 26.6 \text{ mol dm}^{-3}
 \end{aligned}$$

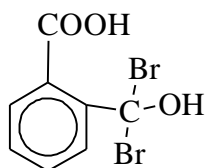
(iii) When a catalyst is present,

- number of reactant particles with at least the activation energy ( $E_{a'(\text{cat})}$ ) increases
- number of effective collisions per unit time taking place in the reaction increases. Rate of reaction is proportional to the frequency of effective collisions.  
Hence, rate of reaction increases.

(iv)



(b) (i)

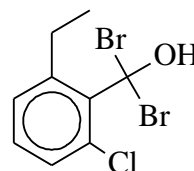
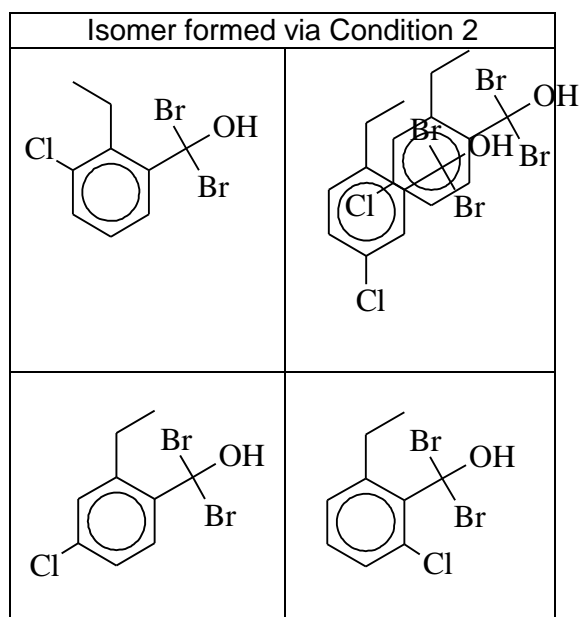
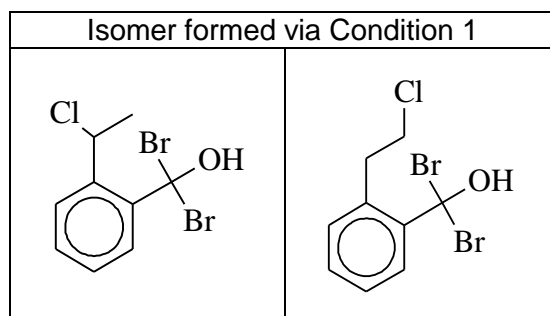


- (ii) Add an equal volume of NaOH(aq) to RX and heat (in a water bath). Cool the mixture and add excess aqueous HNO<sub>3</sub>. Finally, add aqueous AgNO<sub>3</sub>.

For compound W: cream AgBr precipitate was obtained

For compound X: yellow AgI precipitate was obtained

(iii)



Condition 1

Reagent: limited Cl<sub>2</sub>(g)

Conditions: uv light or high temperature

## Section B

- 1 (a) (i) *Order of reaction* is the power to which the concentration of that reactant is raised in the rate equation.

- (ii) Order w.r.t  $O_2$  is zero as the graph of  $[O_2]$  against time is a downward sloping straight line / the gradient of the line i.e. rate of reaction is constant with changing  $[O_2]$ .

When  $[SO_2] = 0.80 \text{ mol dm}^{-3}$ ,

$$r_1, \text{ rate of reaction} = \left| \frac{0.04 - 0.05}{88} \right| = 1.13 \times 10^{-4}$$

When  $[SO_2] = 1.20 \text{ mol dm}^{-3}$ ,

$$r_2, \text{ rate of reaction} = \left| \frac{0.030 - 0.05}{80} \right| = 2.50 \times 10^{-4}$$

$$r_2/r_1 = 2.21 \approx 2.25$$

When  $[SO_2]$  x 1.5 times, rate of reaction x 2.25 times, reaction is second order w.r.t  $SO_2$ .

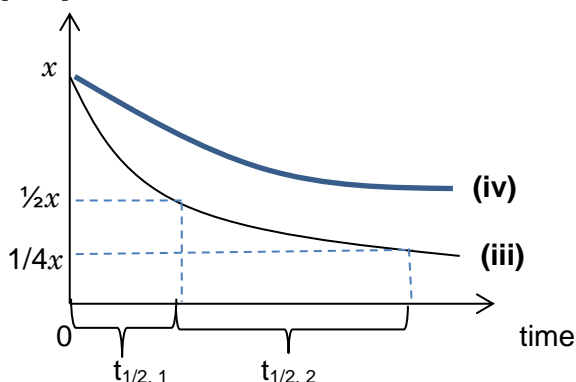
- (iii)  $\text{rate} = k[SO_2]^2$

When  $[SO_2] = 0.8 \text{ mol dm}^{-3}$ ,

$$k = 1.77 \times 10^{-4} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

( $k = 1.74 \times 10^{-4}$  if  $[SO_2] = 1.2 \text{ mol dm}^{-3}$ )

- (iii)  $[SO_2] / \text{mol dm}^{-3}$



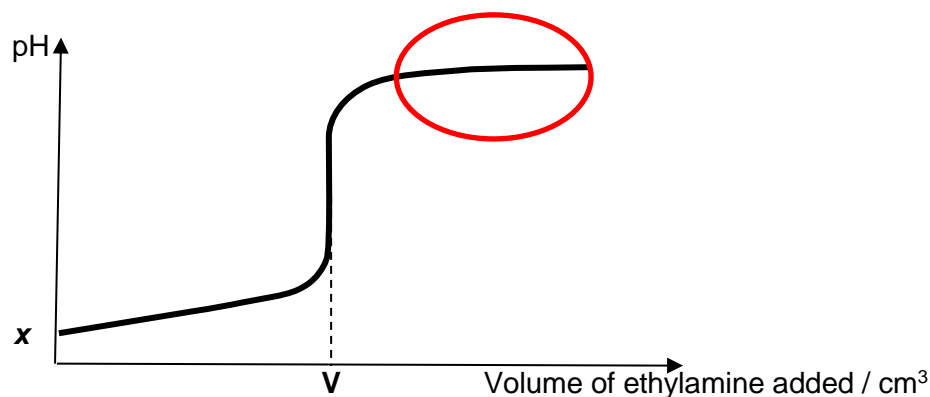
- (b) Weak base is one which **dissociates partially** in water to **give hydroxide ions**.

(c) 
$$K_b = \frac{[CH_3CH_2NH_3^+][OH^-]}{[CH_3CH_2NH_2]} \text{ mol dm}^{-3}$$

- (d) (i)  $[H^+] = 0.20 \text{ mol dm}^{-3}$   
 $\text{pH} = -\lg(0.20)$   
 $= 0.699$

- (ii)  $2CH_3CH_2NH_2 + H_2SO_4 \rightarrow (CH_3CH_2NH_3^+)_2SO_4^{2-}$   
 amount of sulfuric acid =  $10.0/1000 \times 0.1$   
 $= 0.001 \text{ mol}$   
 amount of  $CH_3CH_2NH_2 = 0.002 \text{ mol}$   
 equivalence volume =  $0.002 / 0.10$   
 $= 20.0 \text{ cm}^3$

(iii)



(iv) This is a strong acid–weak base titration and hence the salt is acidic. Bromocresol green will be a suitable indicator as the pH transition range of the indicator lies within the rapid pH change over the equivalence point. Colour change at the end-point will be yellow to green/blue.

(e)  $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCOOH}$   
 $\text{CH}_3\text{CH}_2\text{COOH}$

(f) 3–hydroxypentanoic acid is a stronger acid than pentanoic acid. –OH, hydroxyl group is electron–withdrawing and hence disperse the negative charge of the conjugate base. This stabilises the conjugate base and makes 3–hydroxypentanoic acid a stronger acid.

2 (a) (i)  $\text{Al}_2\text{O}_3$  is insoluble in water. Hence bioavailability of  $\text{Al}^{3+}$  is not increased in solution

(ii)  $\text{AlCl}_3$  undergoes hydrolysis to give an acidic solution.

The high charge density of hydrated  $\text{Al}^{3+}$  ion enables it to attract electrons away from one of its surrounding water molecules, thereby polarising or weakening the O–H bond which results in the release of a proton.



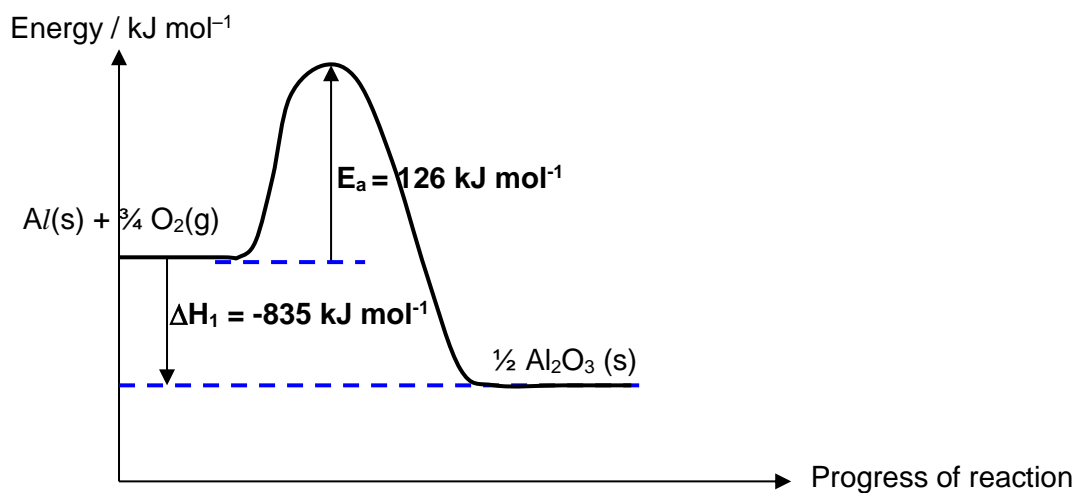
(b) (i) Enthalpy change of combustion of  $\text{Al}$  or  $\frac{1}{2} \Delta H_f(\text{Al}_2\text{O}_3)$

(ii) Enthalpy change of formation is the energy change when 1 mol of  $\text{O}^{2-}(\text{g})$  is formed from  $\text{O}_2(\text{g})$ .

$$\begin{aligned} \Delta H_3 &= 950 \times \frac{3}{2} \\ &= +1.43 \times 10^3 \text{ kJ mol}^{-1} \end{aligned}$$

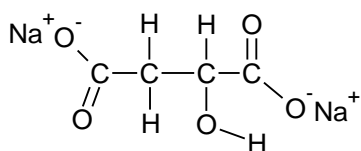
(iii)  $\begin{aligned} \Delta H_4 &= -\Delta H_3 - \Delta H_2 + \Delta H_1 \\ &= -(1.43 \times 10^3) - (5459) - 835 \\ &= -7.72 \times 10^3 \text{ kJ mol}^{-1} \end{aligned}$

(iv)



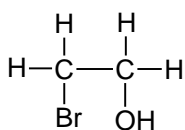
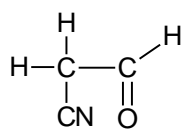
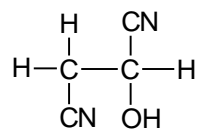
(v) Activation energy of the reverse reaction =  $835 + 126$   
 $= 961 \text{ kJ mol}^{-1}$

(c)



(d)

(i)

**A****B****C**

(ii)

Reaction I – aqueous bromine

Reaction II –  $\text{K}_2\text{Cr}_2\text{O}_7$  in dilute  $\text{H}_2\text{SO}_4$ , heat with immediate distillation

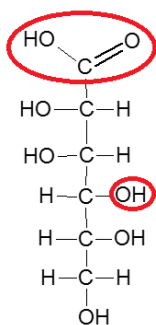
Reaction III – KCN in ethanol, heat under reflux

Reaction V – dilute  $\text{H}_2\text{SO}_4$ , heat under reflux



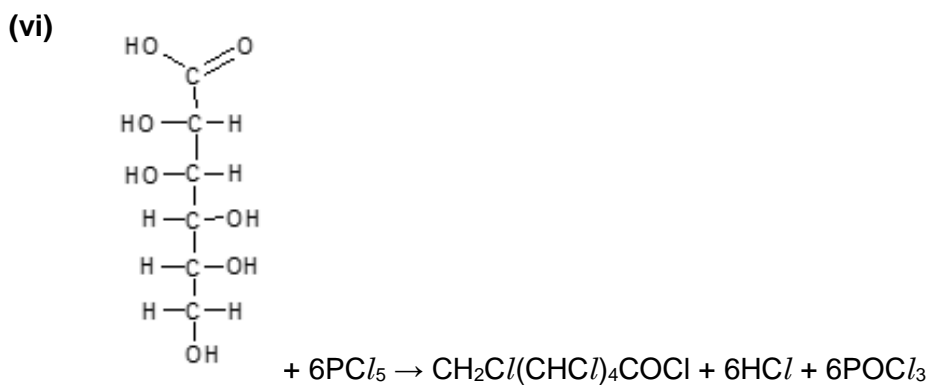
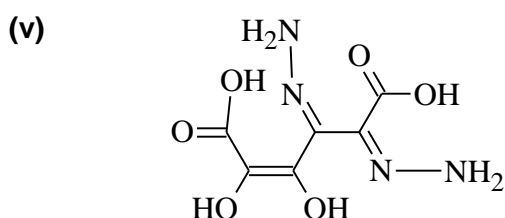
3 (a) (i) Alcohol and ester.

(ii) Condensation.



(iii) Ascorbic acid has a simple molecular structure. The hydrogen bonds formed between ascorbic acid and water molecules releases sufficient energy to overcome the intermolecular hydrogen bonding between ascorbic acid and also between water.

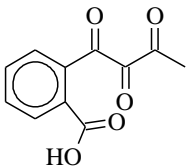
(iv) Glucose is more soluble in water than ascorbic acid as there are more alcohol groups available to form more extensive hydrogen bonds with water.



(vii)

Carbon atom	Type of hybridisation	Shape	No. of $\sigma$ and $\pi$ bonds
$\text{C}_1$	$\text{sp}^3$ hybridised	tetrahedral	$4\sigma$ bonds
$\text{C}_2$	$\text{sp}^2$ hybridised	trigonal planar	$3\sigma$ and $1\pi$ bonds

(b)

Observations		Deductions	
Compound <b>A</b> gives a yellow precipitate with alkaline aqueous iodine.		<ul style="list-style-type: none"> <li>Compound <b>A</b> undergoes oxidation.</li> <li>⇒ either <math>-\text{COCH}_3</math> or <math>-\text{CH}(\text{OH})\text{CH}_3</math> present.</li> </ul>	
When treated with hot concentrated $\text{KMnO}_4$ , the product <div style="text-align: center;">  <p>is formed.</p> </div>		<ul style="list-style-type: none"> <li>Compound <b>A</b> undergoes oxidation.</li> <li>⇒ Alkene is present.</li> <li>⇒ Secondary alcohol may be present.</li> </ul>	
One mole of Compound <b>A</b> also reacts with one mole of bromine in tetrachloromethane		<ul style="list-style-type: none"> <li>Compound <b>A</b> undergoes (electrophilic) addition.</li> <li>⇒ One <math>\text{C}=\text{C}</math> bond is present.</li> </ul>	
but does not react with Na.		<ul style="list-style-type: none"> <li>Compound <b>A</b> does not undergo acid–metal displacement / redox with Na.</li> <li>⇒ no alcohol, or carboxylic acid present.</li> </ul>	
Compound <b>B</b> is formed when $\text{HCl}(\text{g})$ is added to Compound <b>A</b> .		<ul style="list-style-type: none"> <li>Compound <b>A</b> undergoes (electrophilic) addition.</li> <li>⇒ Alkene is present.</li> <li>⇒ Compound <b>B</b> is a chloroalkane.</li> </ul>	
When Compound <b>B</b> is heated with aqueous NaOH, followed by aqueous $\text{AgNO}_3$ , Compound <b>C</b> and a white precipitate is formed.		<ul style="list-style-type: none"> <li>Compound <b>B</b> undergoes (nucleophilic) substitution.</li> <li>⇒ Alcohol present in Compound <b>C</b>.</li> </ul>	
Compound <b>C</b> does not react with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ .		<ul style="list-style-type: none"> <li>Compound <b>C</b> does not undergo oxidation.</li> <li>⇒ Tertiary alcohol present in Compound <b>C</b>.</li> </ul>	
Compound <b>A</b>		Compound <b>B</b>	Compound <b>C</b>
