

1. The balanced equation that represents the combustion of ethanol is \_\_\_i\_\_\_ and the sign of the enthalpy change for the reaction is \_\_\_ii\_\_\_.

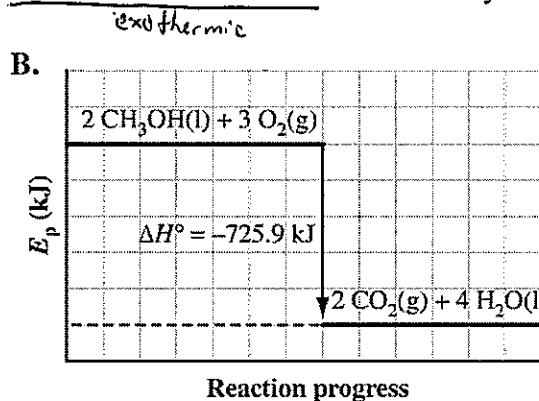
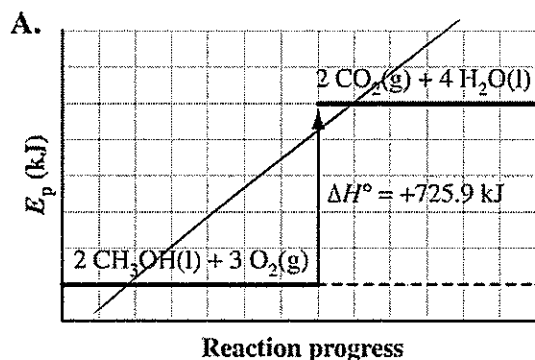
The statement above is completed by the information in row

Row	i	ii
(A.)	$C_2H_5OH(l) + 3 O_2(g) \rightarrow 2 CO_2(g) + 3 H_2O(g)$	negative
B.	$C_2H_5OH(l) + 3 O_2(g) \rightarrow 2 CO_2(g) + 3 H_2O(g)$	positive
C.	$2 C_2H_5OH(l) + 7 O_2(g) \rightarrow 4 CO_2(g) + 6 H_2O(g)$	negative
D.	$2 C_2H_5OH(l) + 7 O_2(g) \rightarrow 4 CO_2(g) + 6 H_2O(g)$	positive

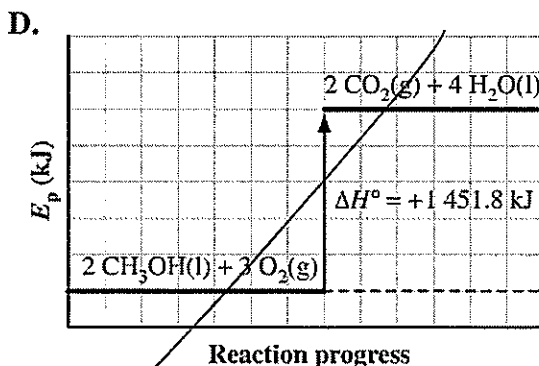
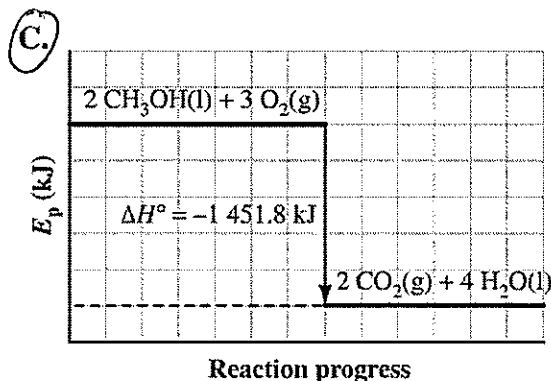
Use the following information to answer the next question.

Methanol is used as fuel in racing cars. The energy content of methanol can be determined by calorimetry in a closed system.

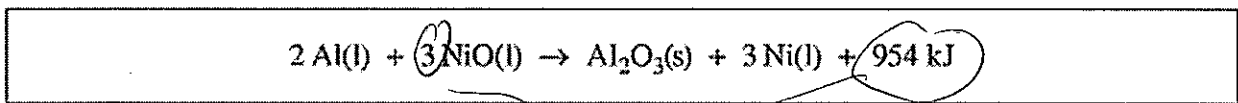
2. Which of the following diagrams represents the combustion of methanol in a closed system?



$$\Delta_r H = \sum n \Delta_f H_m \text{ products} - \sum n \Delta_f H_m \text{ reactant}$$



Use the following information to answer the next question.



3. The molar enthalpy of reaction for NiO(l) in the reaction represented by the equation above is  
 A. +954 kJ/mol      B. +318 kJ/mol      (C) -318 kJ/mol      D. -954 kJ/mol

$$\Delta_r H_m = \frac{\Delta_r H}{n} = \frac{-954 kJ}{3 \text{ mol}} = -318 kJ/mol$$

Use the following information to answer the next question.

Reactions		
1	Formation of carbon monoxide	$\Delta H^\circ = -110.5 \text{ kJ/mol}$
2	Formation of nitrogen monoxide	$\Delta H^\circ = +91.3 \text{ kJ/mol}$
3	Decomposition of hydrogen peroxide	$\Delta H^\circ = -187.8 \text{ kJ/mol}$
4	Decomposition of dinitrogen tetroxide	$\Delta H^\circ = +11.1 \text{ kJ/mol}$
5	$\text{Mn(s)} + \text{O}_2(\text{g}) \rightarrow \text{MnO}_2(\text{s}) + 520 \text{ kJ}$	
6	$2 \text{ Ga(s)} + \text{O}_2(\text{g}) + 559 \text{ kJ} \rightarrow 2 \text{ GaO(g)}$	
7	$\text{F}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{F}_2\text{O}_2(\text{g})$	$\Delta H^\circ = +19.2 \text{ kJ/mol}$
8	$\text{N}_2\text{O}_5(\text{g}) \rightarrow \text{N}_2(\text{g}) + \frac{5}{2} \text{O}_2(\text{g})$	$\Delta H^\circ = -13.3 \text{ kJ/mol}$

Reaction progress

### Numerical Response

1. The enthalpy diagram above could be used to represent the reaction numbered 2, 4, 6, and 7.  
(Record all four digits of your answer in any order in the numerical response section of your answer sheet)

Use the following information to answer the next question.

Some drag-racing vehicles burn methanol, as represented by the following equation.

$$2 \text{ CH}_3\text{OH(l)} + 3 \text{ O}_2(\text{g}) \rightarrow 2 \text{ CO}_2(\text{g}) + 4 \text{ H}_2\text{O(g)} \quad \Delta H = -1275.8 \text{ kJ}$$

### Numerical Response

2. The mass of methanol that burns to produce an enthalpy change of  $-8.50 \times 10^4 \text{ kJ}$  is 4.27 kg  
(Record your three digit answer in the numerical response section of your answer sheet)

$$\Delta_r H = n \Delta_r H_m$$

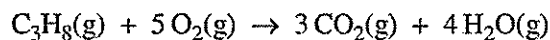
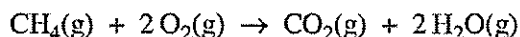
$$n = \frac{\Delta_r H}{\Delta_r H_m} = \frac{-8.50 \times 10^4 \text{ kJ}}{-637.9 \text{ kJ/mol}} = 133.249 \dots \text{ mol}$$

$$m = nM = (133.249 \dots \text{ mol})(32.05 \text{ g/mol}) = 4270.6 \dots \text{ g} = 4.27 \text{ kg}$$



Use the following information to answer the next question.

In an experiment, technicians compared the use of methane and propane as fuels. They burned samples of the two fuels and used a calorimeter to determine the energy transferred. The combustion reactions are represented by the following equations.



4. Which of the following statements correctly classifies two of the variables in the technicians experiment

- A
- A. The manipulated variable is the type of fuel, and a controlled variable is the type of calorimeter.
  - B. The responding variable is the final temperature of the water, and a controlled variable is the type of fuel.
  - C. The manipulated variable is the type of fuel, and a responding variable is the temperature change of the fuel.
  - D. The responding variable is the final temperature of the water, and a controlled variable is the temperature change of the fuel.

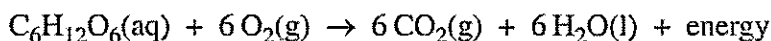
Use the following information to answer the next question.

The reactions for photosynthesis and cellular respiration are represented by the following equations.

**Photosynthesis**



**Cellular Respiration**



5. Which of the following statements accurately describes photosynthesis and cellular respiration?

- D
- A. The products of photosynthesis have less potential energy than the reactants, whereas in cellular respiration, the reactants have less potential energy than the products.
  - B. Photosynthesis traps energy in the form of glucose, and cellular respiration absorbs energy required by all organisms.
  - C. Photosynthesis is an exothermic process, and cellular respiration is an endothermic process.
  - D. Photosynthesis requires energy, and cellular respiration produces energy.

Use the following information to answer the next two questions.

Sucrose,  $C_{12}H_{22}O_{11}(s)$ , is commonly used to sweeten food. In order to determine the molar enthalpy of combustion for sucrose, a technician burns a 0.0150 mol sample of sucrose using a copper calorimeter that contains 250.0 g of water. The combustion of sucrose is represented by the following equation.



6. If the temperature change of the water in the calorimeter is  $55.5^\circ C$ , then the experimental molar enthalpy of combustion for sucrose is approximately

- A.  $-8.72 \times 10^{-1} \text{ kJ/mol}$      B.  $-1.40 \times 10^1 \text{ kJ/mol}$      C.  $-5.81 \times 10^1 \text{ kJ/mol}$      D.  $-3.88 \times 10^3 \text{ kJ/mol}$

7. If included as a term in the equation above, energy is a i, and the water in the calorimeter undergoes a change primarily in ii energy.

The statement above is complete by the information in row

Row	i	ii
A.	reactant	kinetic
B.	reactant	potential
<input checked="" type="radio"/> C.	product	kinetic
D.	product	potential

Use the following information to answer the next question.



**Numerical Response**

$$\Delta_r H = \sum n \Delta_f H_m - \sum n \Delta_f H_m = [(2 \text{ mol})(-436.5 \text{ kJ/mol}) + (3 \text{ mol})(0 \text{ kJ/mol})] - [(2 \text{ mol})(-397.7 \text{ kJ/mol})]$$

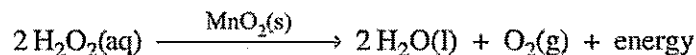
3. The enthalpy change for the reaction represented by the equation above is +/- 77.6 kJ.

(Record your three digit answer in the numerical response section of your answer sheet)

$$\Delta_r H_c = -77.6 \text{ kJ}$$

Use the following information to answer the next question.

Hydrogen peroxide solutions are available commercially because hydrogen peroxide decomposes very slowly. When  $MnO_2(s)$  is added to a solution of hydrogen peroxide, the hydrogen peroxide decomposes rapidly, as represented by the following equation.

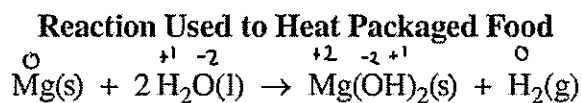


8. In the reaction represented by the equation above,  $MnO_2(s)$  acts to

- A. increase the activation energy     B. reduce the activation energy  
 C. reduce the net energy released by the reaction     D. increase the energy released by the reaction

Use the following information to answer the next question.

Some foods are available in insulated packages containing chemicals that produce an exothermic reaction that heats the food. When excess water and powdered magnesium metal react in the presence of an iron catalyst, energy is released. The reaction is represented by the following equation.



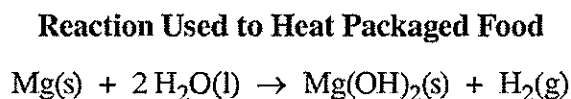
9. In the reaction used to heat packaged food, the oxidizing agent is i, and the amount of electrons transferred when 1 mol of powdered magnesium reacts is ii.

The statement above is completed by the information in row

Row	i	ii
A.	Mg(s)	1 mol
B.	Mg(s)	2 mol
C.	H <sub>2</sub> O(l)	1 mol
<b>D.</b>	H <sub>2</sub> O(l)	2 mol

Use the following information to answer the next question.

Some foods are available in insulated packages containing chemicals that produce an exothermic reaction that heats the food. When excess water and powdered magnesium metal react in the presence of an iron catalyst, energy is released. The reaction is represented by the following equation.



**Statements About the Heating Reaction**

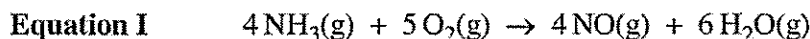
- 1 The rate of reaction increases.
- 2 The  $\Delta H^\circ$  value for the reaction increases.
- 3 The  $\Delta H^\circ$  value for the reaction stays the same.
- 4 The potential energy of the products increases.

10. Which of the statements numbered above describes the effect of the iron catalyst on the reaction used to heat packaged food?

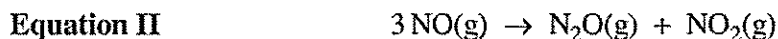
- A **A.** 1 only      B. 1 and 3      C. 1, 2 and 4      D. 2 and 4 only

Use the following information to answer the next two questions.

Nitrogen monoxide gas, which is used to treat some pulmonary diseases, is transported in pressurized gas cylinders. Nitrogen monoxide gas is produced by reacting ammonia gas and oxygen gas, as represented by the following equation.



Under high pressure in the gas cylinder, nitrogen monoxide gas can undergo the reaction represented by the following equation.



**Numerical Response**

4. The oxidation number for nitrogen in

$\text{NH}_3(\text{g})$  is +/- 3 (Record in the first box)

$\text{NO}(\text{g})$  is +/- 2 (Record in the second box)

$\text{N}_2\text{O}(\text{g})$  is +/- 1 (Record in the third box)

$\text{NO}_2(\text{g})$  is +/- 4 (Record in the fourth box)

11. During the reaction represented by equation II, nitrogen monoxide undergoes i and ii electrons.

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	disproportionation	oxygen gains and loses
<b>B.</b>	disproportionation	nitrogen gains and loses
C.	oxidation	oxygen loses
D.	oxidation	nitrogen loses

Use the following information to answer the next question.

Under acidic conditions, certain organisms carry out anaerobic respiration by using oxidizing agents other than oxygen. A half-reaction involved in anaerobic respiration is represented by the following **unbalanced** equation.



**Numerical Response**

5. When the equation above is balanced using lowest whole-number coefficients, the coefficient of

$\text{SO}_4^{2-}(\text{aq})$  is 1 (Record in the first box)

$\text{H}^+(\text{aq})$  is 9 (Record in the second box)

$\text{e}^-$  is 8 (Record in the third box)

$\text{H}_2\text{O}(\text{l})$  is 4 (Record in the fourth box)

balance O first with H<sub>2</sub>O  
then H with H<sup>+</sup>  
then charge with e<sup>-</sup>

Use the following information to answer the next question.

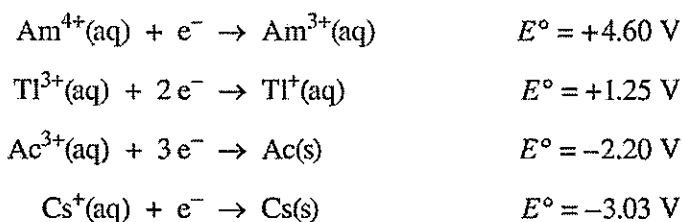
### Reduction and Oxidation Statements

- I Solid magnesium reacts to form  $\text{Mg}^{2+}$  ions.
- II Tin metal forms stable ions by losing electrons.
- III Oxygen gas forms stable ions by gaining electrons.
- IV Zinc metal is extracted from ore containing  $\text{ZnS}(s)$ .
- V The oxidation number of sulfur changes from +2 to -2.
- VI The oxidation number of sulfur changes from +4 to +6.

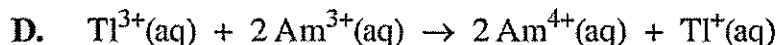
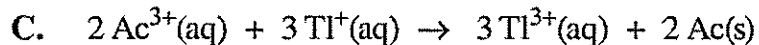
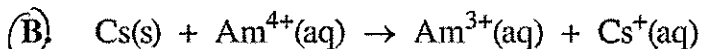
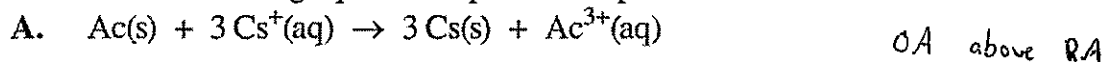
12. The statements numbered above that describe oxidation are *lose electrons*  
A. I, II, and VI    B. I, IV, and VI    C. II, IV and V    D. III, IV and V

Use the following information to answer the next question.

### Reduction Half-Reactions

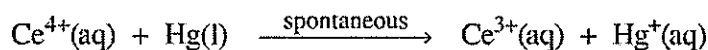
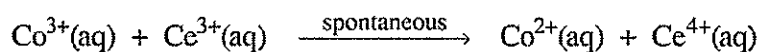


13. Which of the following equations represents a spontaneous oxidation-reduction reaction?

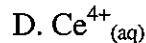
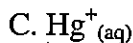
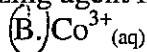
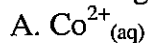


Use the following information to answer the next question.

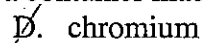
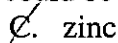
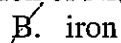
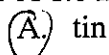
### Spontaneous Redox Reactions



14. The strongest oxidizing agent in the equations above is



15. A 1.0 mol/L solution of  $\text{Ni}(\text{NO}_3)_2(\text{aq})$  could be stored in a container made of



- has to be something it ( $\text{Ni}^{2+}$ ) won't react with  
- we don't want a spontaneous reaction occurring

Use the following information to answer the next question.

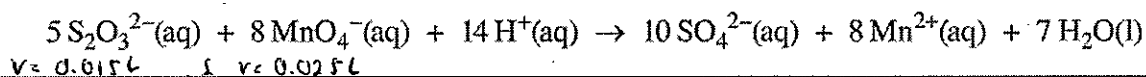
Ethene is produced from ethane found in natural gas. The ethene is transported through iron pipelines to chemical plants in order to be converted into other products, such as ethylene glycol and polyethylene. The buried iron pipeline is subject to corrosion, due in part to trapped air in damp soil.

16. Which of the following actions could prevent the corrosion of the pipeline?

- A. Using a pipeline made of copper  
 B. Using a pipeline made of chromium  
 C. Connecting strips of lead to the pipeline at appropriate intervals  
 D. Connecting strips of zinc to the pipeline at appropriate intervals

Use the following information to answer the next question.

A 15.0 mL sample of  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  is titrated to a pink endpoint with 25.0 mL of 12.3 mmol/L acidified  $\text{KMnO}_4(\text{aq})$ . This titration reaction is represented by the equation



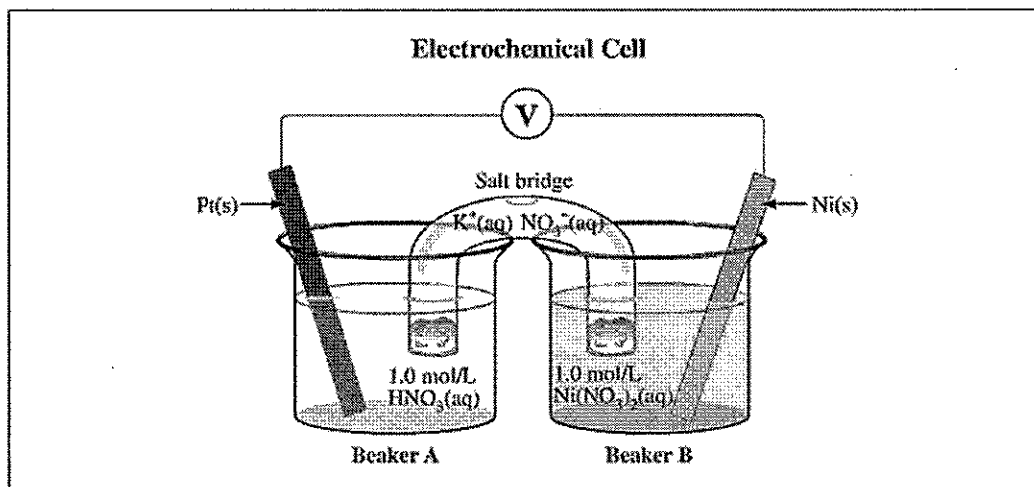
$n = 2$   
 $V = 0.015 \text{ L}$   
 $c = 12.3 \text{ mmol/L}$   
 $V = 0.025 \text{ L}$

**Numerical Response**

6. The concentration of the  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  solution is 12.8 mmol/L. (Record your answer to 3 digits)

$c = \frac{n}{V}$

Use the following information to answer the next question.



**Numerical Response**

7. If the standard silver reduction half-reaction had been chosen as the reference half reaction instead of the hydrogen reduction half-reaction, then the electrical potential of the cell represented by the diagram above would be +/- 1.06 V. (Record your answer to 3 digits)

$E_{\text{cell}} = E_{\text{cath}}^{\circ} - E_{\text{anode}}^{\circ}$

- difference between two half reactions will always be the same regardless of what is the reference half cell



Use the following information to answer the next question.

**A Standard Copper-Silver Cell**

**Descriptions of Electrochemical Cells**

- 1 This is a voltaic cell.
- ~~2 This is an electrolytic cell.~~
- ~~3 The mass of Cu(s) increases.~~
- 4 The mass of Ag(s) increases.
- 5 A spontaneous reaction occurs.
- ~~6 A nonspontaneous reaction occurs.~~
- 7 Anions flow toward the Cu(s) electrode.
- ~~8 Anions flow toward the Ag(s) electrode.~~

**Numerical Response**

8. The descriptions above that apply to this operating standard copper-silver cell are numbered 1, 4, 5 and 7. (Record all four digits in the numerical response section of your answer sheet)

Use the following information to answer the next question.

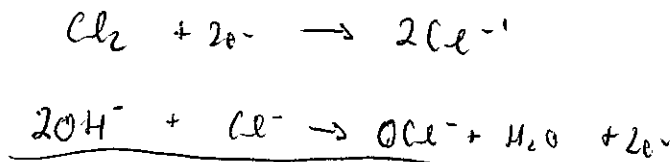
One type of bleach is manufactured by adding chlorine gas to a sodium hydroxide solution, as represented by the equilibrium equation below.

$$\text{Cl}_2(\text{g}) + 2\text{OH}^-(\text{aq}) \rightleftharpoons \text{OCl}^-(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$$

If the pH of this equilibrium system is maintained at approximately 8, then  $\text{OCl}^-(\text{aq})$  and  $\text{Cl}^-(\text{aq})$  are the predominant chlorine-containing species in the solution.

17. The  $E_{\text{net}}^{\circ}$  for the forward reaction is  
 A. +2.20 V    B. +1.36 V    C. +0.55 V    **D. +0.52 V**

$$\begin{aligned}
 E_{\text{net}} &= E_{\text{cath}}^{\circ} - E_{\text{anode}}^{\circ} \\
 &= +1.36\text{V} - 0.84\text{V} \\
 &= +0.52\text{V}
 \end{aligned}$$



Use the following information to answer the next question.

**Statements About Electrochemical Cells**

- 1 The net potential is positive. *voltaic*
- 2 The net potential is negative. *electrolytic*
- 3 Reduction occurs at the cathode. *both*
- 4 Cations travel toward the cathode. *both*
- 5 Electrons travel toward the cathode. *both*
- 6 A flow of electrons is spontaneously generated. *voltaic*
- 7 The strongest oxidizing agent reacts at the cathode. *both*

**Numerical Response**

9. The statements above that apply to both a voltaic cell and an electrolytic cell are numbered 3, 4, 5, and 7. (Record all four digits in the numerical response section of your answer sheet)

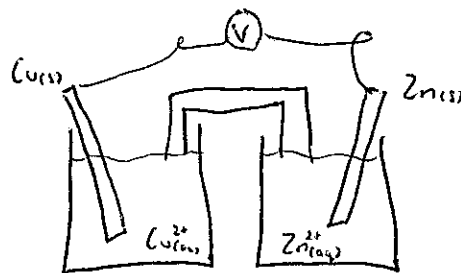
Use the following information to answer the next question.

A student sets up a standard copper–zinc voltaic cell in a laboratory and measures the net potential.

18. Compared with solid zinc, solid copper is a i reducing agent, and during the operation of this cell, the zinc electrode ii electrons.

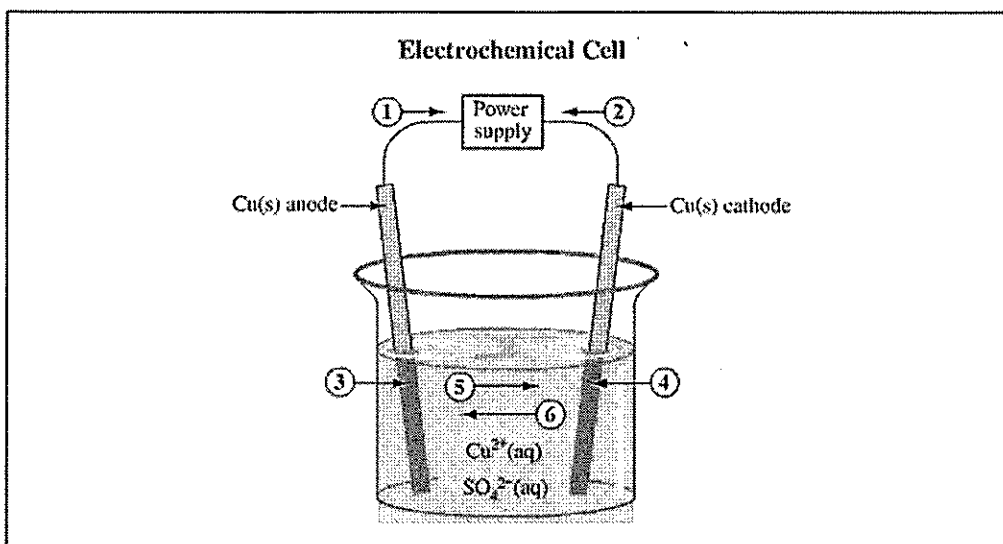
The statement above is completed by the information in row

Row	i	ii
A.	weaker	gains
<b>B.</b>	weaker	loses
C.	stronger	gains
D.	stronger	loses



B

Use the following information to answer the next two questions.



19. If a current of 0.850 A is applied to the electrochemical cell above for 60.0 min, then the mass of copper produced is  
 A. 0.0168 g    **(B)** 1.01 g    C. 2.02 g    D. 4.03 g

$$\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu(s)}$$

$$n_e = \frac{I \cdot t}{F}$$

$$= \frac{(0.850 \text{ A})(3600 \text{ s})}{9.65 \times 10^4 \text{ C/mol}}$$

$$\approx 0.0317 \text{ mol } e^-$$

$$n = 0.01585 \text{ mol}$$

$$M = 63.55 \text{ g/mol}$$

$$m = n \cdot M$$

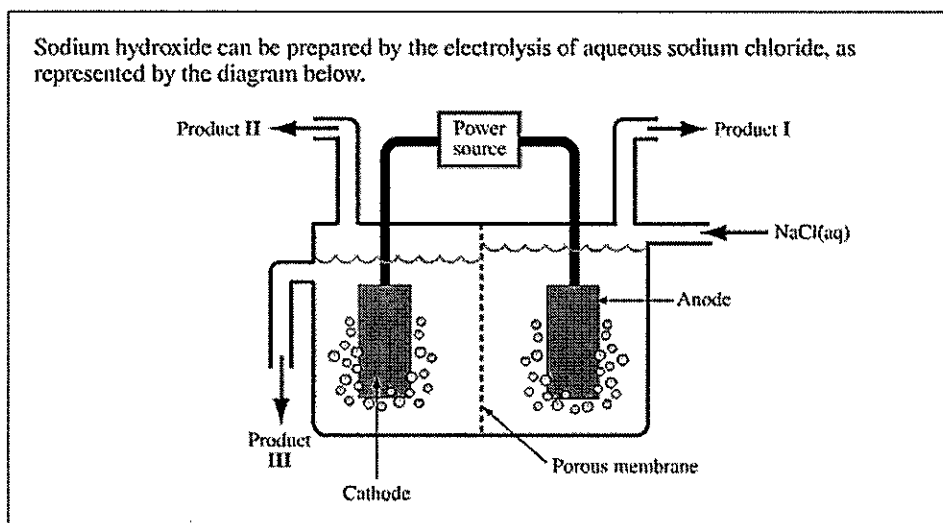
$$= 1.007 \text{ g}$$

**Numerical Response**

10. Match the numbers on the electrochemical cell above with the descriptors below

- Increases in mass                    4 (Record in the first box)  
 Movement of cations                5 (Record in the second box)  
 Movement of electrons             1 (Record in the third box)  
 Site where oxidation occurs        3 (Record in the fourth box)

Use the following information to answer the next question.



20. During the electrolysis of a sodium chloride solution the reduction reaction is

- (A)**  $2\text{H}_2\text{O(l)} + 2e^- \rightleftharpoons \text{H}_2\text{(g)} + 2\text{OH}^-\text{(aq)}$   
~~B.~~  $2\text{H}_2\text{O(l)} \rightleftharpoons \text{O}_2\text{(g)} + 4\text{H}^+\text{(aq)} + 4e^-$  oxidation  
~~C.~~  $\text{Cl}_2\text{(g)} + 2e^- \rightleftharpoons 2\text{Cl}^-\text{(aq)}$  reduction  
~~D.~~  $2\text{Cl}^-\text{(aq)} \rightleftharpoons \text{Cl}_2\text{(g)} + 2e^-$  oxidation

not in the cell

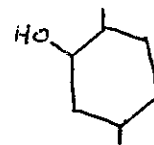
21. The molecular formula for 2,5-dimethylcyclohexan-1-ol is

A.  $C_6H_6O$

B.  $C_6H_{12}O$

C.  $C_8H_{13}O$

D.  $C_8H_{16}O$



Use the following information to answer the next two questions.

Organic Acids		
1	Butanoic acid	$C_3H_7COOH(l)$
2	Methanoic acid	$HCOOH(l)$
3	Octanoic acid	$C_7H_{15}COOH(l)$
4	Octadecanoic acid	$CH_3(CH_2)_{16}COOH(l)$

22. Butanoic acid can be described as an i compound, and the functional group in butanoic acid is ii.

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
<del>A.</del>	aromatic	a carboxyl
<del>B.</del>	aromatic	an ester
<input checked="" type="radio"/> C.	aliphatic	a carboxyl
D.	aliphatic	an ester

aromatic - contains a benzene ring  
aliphatic - no benzene ring

### Numerical Response

11. Listed in order from the acid that has the **lowest** boiling point to the acid that has the **highest** boiling point, the four organic acids above are numbered

2, 1, 3, and 4.

Lowest  
boiling point

Highest  
boiling point

(Record your four digit answer on the numerical response answer sheet)

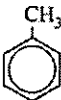

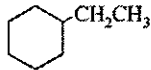
Use the following information to answer the next question.

Molecules	
1	pent-2-ene
2	pent-2-yne
3	cyclopentane
4	methylpropane
5	dimethylpropane
6	ethylcyclopropane
7	methylcyclobutane

### Numerical Response

12. The four molecules listed above that are isomers of  $C_5H_{10}(l)$  are numbered 1, 3, 6, and 7.  
(Record your four digit answer on the numerical response answer sheet)

Use the following information to answer the next question.

Structures and Descriptions			
1		4 Branched	7 Unsaturated double bond
2		5 Unbranched	8 Alkane
3		6 Saturated no double bond	9 Alkene

**Numerical Response**

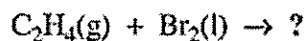
13. The structures and descriptions above that apply to methylcyclopentane are numbered 2, 4, 6, and 8.  
(Record your four digit answer on the numerical response answer sheet)

23. A mixture of liquid methanol and liquid ethanol can be separated by i, and the physical characteristic of these compounds that allows the separation is ii.

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	fractional distillation	solubility
<b>B.</b>	fractional distillation	boiling point
C.	precipitation	solubility
D.	precipitation	boiling point

Use the following information to answer the next question.



24. The reactants above undergo and i reaction, and the product of the reaction is 1,2 dibromo ii.

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	elimination	ethane
B.	elimination	ethene
<b>C.</b>	addition	ethane
D.	addition	ethene

Use the following information to answer the next question.

Ethene is a plant hormone that causes fruits and vegetables to ripen. Ethene can be produced artificially by the reaction represented by the following equation.



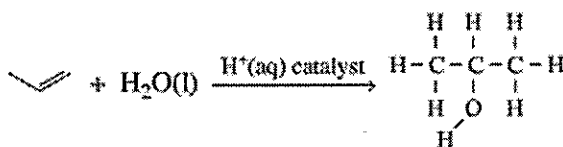
25. Ethene can be described as both an i compound and ii molecule.

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	aliphatic	a saturated
B.	aliphatic	an unsaturated
C.	aromatic	a saturated
D.	aromatic	an unsaturated

Use the following information to answer the next question.

Propan-2-ol can be produced from propene and water, as represented by the following equation.



26. The production of propan-2-ol from propene is i reaction. Propan-2-ol is likely to be ii in water.

The statement above is completed by the information in row

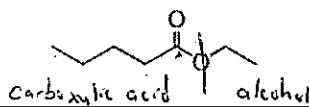
Row	<i>i</i>	<i>ii</i>
A.	a substitution	soluble
B.	a substitution	insoluble
C.	an addition	soluble
D.	an addition	insoluble

27. Which of the following rows identifies a reactant and its product in a polymerization reaction?

Row	Reactant	Product
A.	Ethene	<del>Ethene</del>
B.	Ethene	Polyethene
C.	Propene	<del>Ethene</del>
D.	<del>Propene</del>	Polyethene

Use the following information to answer the next question.

Esters with pleasant odours and flavours are often used as food additives. An ester that is used for its fruity apple flavour is shown below.



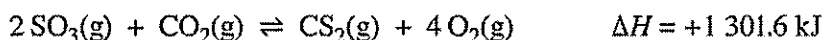
28. The ester shown above could be produced by the reaction of i and ii.

The statement above is completed by the information in row

Row	i	ii
A.	ethanoic acid	pentan-1-ol
B.	ethanoic acid	butan-1-ol
C.	pentanoic acid	propan-1-ol
<b>(D)</b>	pentanoic acid	ethanol

Use the following information to answer the next three questions.

A technician places a sample of sulfur trioxide gas and a sample of carbon dioxide gas in an empty 1.0 L flask and allows them to reach equilibrium at 800 °C. The equilibrium system that is established in the flask is represented by the following equation.



#### Changes to the Equilibrium System

- I The addition of a catalyst
- II A decrease in the volume of the container
- III An increase in the temperature of the system

1301.6 kJ

$$\Delta H = [(1 \text{ mol})(\Delta_f H_m(\text{CS}_2))] - [(2 \text{ mol})(-395.7 \text{ kJ/mol}) + (1 \text{ mol})(-393.5 \text{ kJ/mol})]$$

29. In the reaction represented by the equation above, the molar enthalpy of formation of  $\text{CS}_2(\text{g})$  is **(A)** +116.7 kJ/mol      B. +512.4 kJ/mol      C. +1699.5 kJ/mol      D. +2486.5 kJ/mol

#### Numerical Response

14. If at equilibrium the concentration of  $\text{SO}_3(\text{g})$  is 0.289 mol/L; the concentration of  $\text{CO}_2(\text{g})$  is 0.0180 mol/L; the concentration of  $\text{CS}_2(\text{g})$  is 0.201 mol/L; the concentration of  $\text{O}_2(\text{g})$  is 0.900 mol/L, then the  $K_c$  value for the system at 800°C is 81.7.

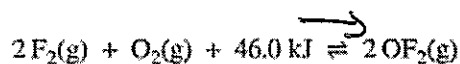
(Record your three-digit answer in the numerical response section of the answer sheet)  $K_c = \frac{[\text{O}_2]^4 [\text{CS}_2]}{[\text{SO}_3]^2 [\text{CO}_2]}$

30. Which of the changes to the equilibrium system numbered above would affect the value of the equilibrium constant?

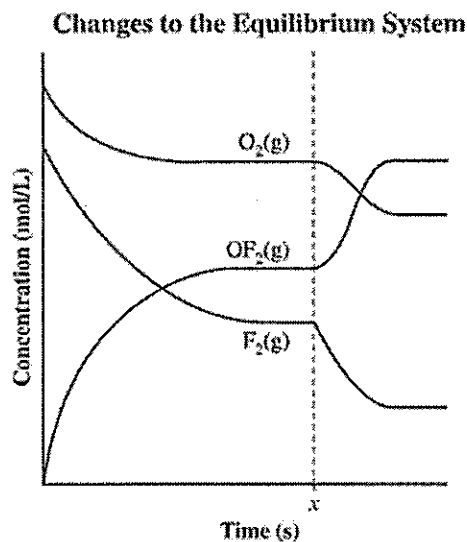
- A. I and III only      B. I, II, and III      C. II only      **(D)** III only

Use the following information to answer the next question.

A technician injected fluorine gas and oxygen gas into an empty 1.0 L reaction vessel. She closed the vessel and allowed the reaction to reach equilibrium, as represented by the following equation.



The technician changed the reaction conditions and allowed a new equilibrium to be established as represented by the graph below.

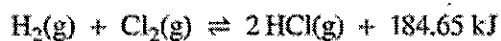


31. Which of the following stresses represents the change in the equilibrium system at time  $x$  on the graph above?

- A. A catalyst is added.                       B. Pressure is decreased.  
 C. Temperature is increased.                 D. Fluorine gas is removed from the vessel.

Use the following information to answer the next question.

**Equilibrium System**



Stresses

- I The addition of  $\text{H}_2(\text{g})$
- II The addition of  $\text{HCl}(\text{g})$
- III The cooling of the equilibrium system
- IV An increase in the volume of the container

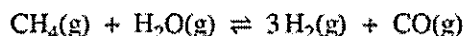
32. The stresses numbered above that would cause the equilibrium system to shift toward the products are

- A. I and III only                      B. I, III and IV                      C. II and III only                      D. II, III and IV



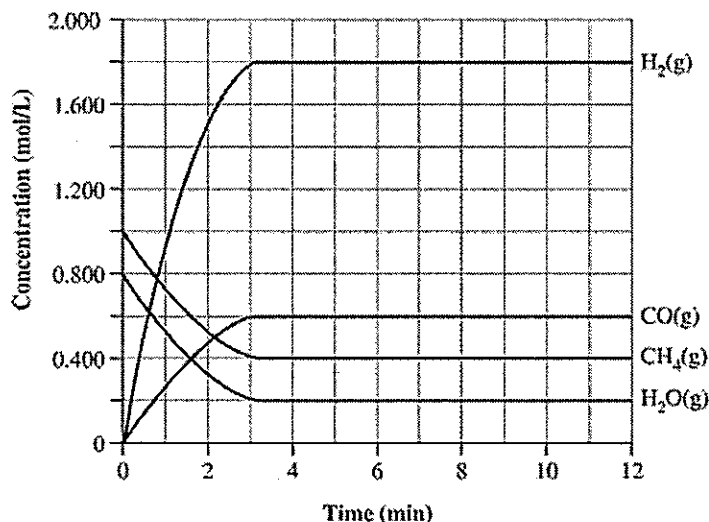
Use the following information to answer the next question.

A technician is producing hydrogen gas. He adds methane gas, steam, and a nickel catalyst to an empty reaction container and allows the system to reach equilibrium. The reaction is represented by the following equation.



The technician's data are represented by the following graph.

Production of Hydrogen at 500 °C



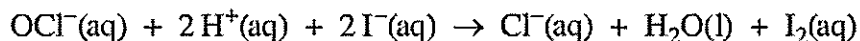
**Numerical Response**

15. The equilibrium constant for the reaction represented in the graph above is 43.7.  
(Record your three-digit answer in the numerical response section of the answer sheet)

$$K_c = \frac{[\text{H}_2]^3 [\text{CO}]}{[\text{CH}_4] [\text{H}_2\text{O}]}$$

Use the following information to answer the next question.

The concentration of aqueous hypochlorite in laundry bleach, NaOCl(aq), can be determined by titrating a sample with an iodide solution, as represented by the following equation.



33. If during the titration the pH of the solution changes from 9.2 to 7.2, then the acidity of the solution i and the hydronium ion concentration ii by a factor of 100.

The statement above is completed by the information in row

Row	i	ii
A.	decreases	increases
B.	decreases	decreases
<b>C.</b>	increases	increases
D.	increases	decreases

Use the following information to answer the next question.

A sample of hydrogen iodide gas, HI(g), is collected and then dissolved in 10.0 L of water.

**Statements About Solutions**

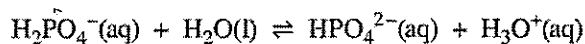
- 1 The pH is less than the pOH.
- 2 The pH is greater than the pOH.
- 3 The solution conducts electricity.
- 4 The solution does not conduct electricity.
- 5 Almost all of the HI(aq) ionizes in the solution.
- 6 Most of the HI(aq) does not ionize in the solution.
- 7 The concentration of  $\text{H}_3\text{O}^+(\text{aq})$  is less than the concentration of  $\text{OH}^-(\text{aq})$ .
- 8 The concentration of  $\text{H}_3\text{O}^+(\text{aq})$  is greater than the concentration of  $\text{OH}^-(\text{aq})$ .

**Numerical Response**

16. The statements above that describe the hydrogen iodide solution are numbered 1, 3, 5, and 8.  
(Record your four-digit answer in the numerical response section of the answer sheet)

Use the following information to answer the next question.

The following equilibrium system maintains a constant pH in the intracellular fluid in the body.



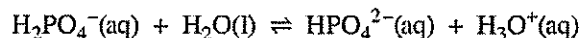
34. A Bronsted-Lowry acid in the equilibrium system represented by the equation above is i, and it will ii the Bronsted-Lowry base.

The statement above is completed by the information in row

Row	i	ii
A.	$\text{H}_2\text{O}(\text{l})$	donate protons to
B.	$\text{H}_2\text{O}(\text{l})$	accept protons from
<input checked="" type="radio"/> C.	$\text{H}_2\text{PO}_4^-(\text{aq})$	donate protons to
D.	$\text{H}_2\text{PO}_4^-(\text{aq})$	accept protons from

Use the following information to answer the next question.

The following equilibrium system maintains a constant pH in the intracellular fluid in the body.



**Terms Associated with Acid–Base Equilibrium Systems**

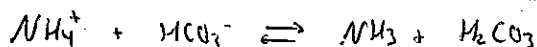
- ✓1 Buffer
- ✓2 Amphiprotic
- ✓3 Polyprotic acid
- ✓4 Polyprotic base
- ✓5 Conjugate acid–base pair

35. Which of the terms numbered above can be used to describe the reaction or the species in the reaction in the equilibrium system above?

- D** A. 1 and 5 only      B. 2 and 3 only      C. 2, 4 and 5 only      D. 1, 2, 3, 4, and 5

Use the following information to answer the next question.

A solution containing the ammonium ion,  $\text{NH}_4^+(\text{aq})$ , is mixed with a solution containing the hydrogen carbonate ion,  $\text{HCO}_3^-(\text{aq})$ .



36. In the forward reaction, the Bronsted-Lowry base is i and its conjugate acid is ii.

The statement above is completed by the information in row

**A**

Row	i	ii
<b>A.</b>	$\text{HCO}_3^-(\text{aq})$	$\text{H}_2\text{CO}_3(\text{aq})$
<b>B.</b>	$\text{HCO}_3^-(\text{aq})$	$\text{NH}_4^+(\text{aq})$
<b>C.</b>	$\text{NH}_4^+(\text{aq})$	$\text{HCO}_3^-(\text{aq})$
<b>D.</b>	$\text{NH}_4^+(\text{aq})$	$\text{NH}_3(\text{aq})$

Use the following information to answer the next question.



37. Which of the following rows identifies the stronger acid and the side of the equilibrium that is favoured?

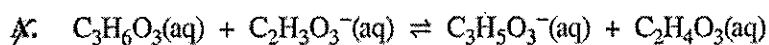
**B**

Row	Stronger Acid	Side Favoured
<b>A.</b>	$\text{HNO}_2(\text{aq})$	products
<b>B.</b>	$\text{HNO}_2(\text{aq})$	reactants
<b>C.</b>	$\text{C}_2\text{H}_5\text{OCOOH}(\text{aq})$	products
<b>D.</b>	$\text{C}_2\text{H}_5\text{OCOOH}(\text{aq})$	reactants

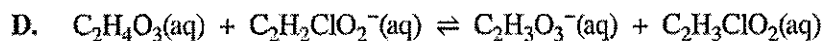
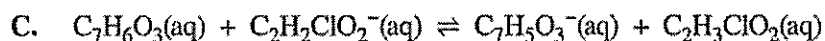
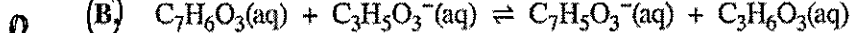
Use the following information to answer the next question.

Monoprotic Organic Acids			
Acid Name	Acid Formula	Conjugate Base Formula	$K_a$
Chloroacetic acid	$C_2H_3ClO_2(aq)$	$C_2H_2ClO_2^-(aq)$	$1.3 \times 10^{-3}$
Salicylic acid	$C_7H_6O_3(aq)$	$C_7H_5O_3^-(aq)$	$1.0 \times 10^{-3}$
Glycolic acid	$C_2H_4O_3(aq)$	$C_2H_3O_3^-(aq)$	$1.5 \times 10^{-4}$
Lactic acid	$C_3H_6O_3(aq)$	$C_3H_5O_3^-(aq)$	$1.4 \times 10^{-4}$

38. The Bronsted-Lowry equation that represents a reaction that favours the products is



acid is above base



Use the following information to answer the next two questions.

Selected Acids and Bases	
I	$H_2O(l)$
II	$OH^-(aq)$
III	$OCl^-(aq)$
IV	$HC_6H_6O_6^-(aq)$
V	$HOCCOO^-(aq)$
VI	$HOCCOOH(aq)$

**C.** 39. The amphiprotic species listed above are

A. I, II and V

B. I, III, and VI

**C.** I, IV and V

D. I, V, and VI

40. The two species listed above that could be combined to prepare a buffer solution are

A. I and II

B. III and IV

C. III and VI

**D.** V and VI

Use the following information to answer the next question.

Sodium fluoroethanoate,  $\text{NaCH}_2\text{FCOO}(\text{aq})$ , is a potent metabolic poison that can be used to kill rodents. The conjugate acid of the fluoroethanoate ion is fluoroethanoic acid,  $\text{CH}_2\text{FCOOH}$ . For this acid,  $K_a = 2.6 \times 10^{-3}$ .

41. The value of  $K_b$  of  $\text{CH}_2\text{FCOO}^- (\text{aq})$  is i and  $\text{CH}_2\text{FCOO}^- (\text{aq})$  is a stronger base than ii.

The statement above is completed by the information in row

Row	i	ii
<b>A.</b>	$3.8 \times 10^{-12}$	$\text{H}_2\text{PO}_4^- (\text{aq})$
<b>B.</b>	$3.8 \times 10^{-12}$	$\text{PO}_4^{3-} (\text{aq})$
<b>C.</b>	$2.6 \times 10^{-3}$	$\text{H}_2\text{PO}_4^- (\text{aq})$
<b>D.</b>	$2.6 \times 10^{-3}$	$\text{PO}_4^{3-} (\text{aq})$

0.15



42. A brand of window cleaning fluid is composed of an ammonia solution, water, and a colouring agent. It has a 0.15 mol/L concentration of  $\text{NH}_3(\text{aq})$ . The pH of this fluid is

- D** A. 2.79      B. 5.04      C. 8.96      **D** 11.21

$$K_b = \frac{K_w}{K_a} = \frac{10^{-14}}{5.6 \times 10^{-10}} = 1.78 \times 10^{-5}$$

43. The concentration of  $\text{H}_3\text{O}^+ (\text{aq})$  in a 0.040 mol/L  $\text{H}_2\text{S}(\text{aq})$  solution is

- B** A.  $3.0 \times 10^{-4}$  mol/L      **B**  $6.0 \times 10^{-5}$  mol/L  
C.  $2.2 \times 10^{-6}$  mol/L      D.  $3.6 \times 10^{-9}$  mol/L

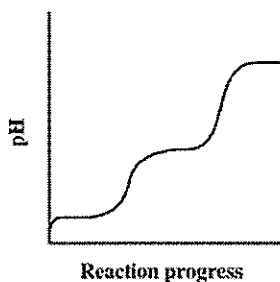
$$K_b = \frac{[\text{OH}^-][\text{NH}_4^+]}{[\text{NH}_3]}$$

$$\text{pOH} = -\log[\text{OH}^-] \quad \text{pH} = 14 - \text{pOH}$$

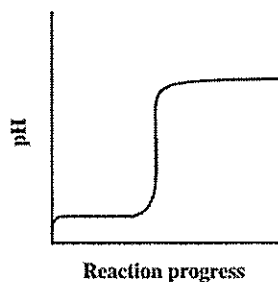
$$1.78 \times 10^{-5} = \frac{x^2}{0.15} \quad x = [\text{OH}^-] = 0.0016$$

44. Which of the following pH curves represents the titration of an acid with a strong base, if one intermediate amphiprotic substance is produced?

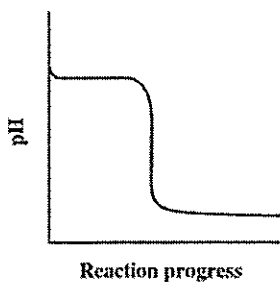
**A**



**B.**



**C.**



**D.**

