Released Items

Chemistry 30

Diploma Examinations Program 2019

Alberta

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General Audience		
Others		

Alberta Education, Government of Alberta

2019–2020

Chemistry 30–1 Released Items

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Contents

Introduction

The questions presented in this booklet are from the *November 2018 Chemistry 30 Diploma Examination*. This material, along with the *Program of Studies*, the *Chemistry 30 Information Bulletin*, and the *Student-based Performance Standards*, can provide insights that assist you with decisions relative to instructional programming.

These examination items are released in both English and French by the Provincial Assessment Sector.

Chemistry 30 Diploma Examination November 2018 Key

Key: MC—Multiple Choice; NR—Numerical Response
R/U—Remembering/Understanding; A—Application; HMA—Higher Mental Activity

Question	Key	Outcome	Cognitive Level
MC1	C	A1.9k	R/U
NR1	235 (any order)	A2.3k, A2.3s	A
MC2	B	A1.5k, A1.1s, A1.3s	HMA
MC3	D	A2.1k, A2.4k	A
NR2	117	A1.8k, A1.2s	A
MC4	A	A2.3k, A2.3s, A2.1sts	A
MC5	B	A1.5k, A2.1sts	A
NR3	2367 (any order)	A1.4k, A1.6k, A1.10k, A2.2k, A2.1sts	A
NR4	30.6	A1.3k, A1.1sts	A
MC6	A	A1.2k, A2.2k, A1.1sts	A
MC7	C	A1.7k, A1.1sts	A
MC8	B	A1.6k	A
MC9	D	B1.4k	A
MC10	B	B1.3k	A
MC11	A	B1.1k, B1.2k	A
NR5	5687	B1.5k, B1.2s, B1.3s	HMA
MC12	C	B1.6k, B1.3s	HMA
NR6	4646	B1.2k	A
MC13	D	B1.7k	HMA
MC14	A	B1.2s	HMA
MC15	C	B1.8k, B1.4s	A
MC16	B	B2.1k, B2.2k, B2.2s, B2.2sts	R/U
MC17	C	B2.1k, B2.3k, B2.1sts	A
NR7	0.74	B2.6k, B2.1sts	A
MC18	B	B2.3k, B2.1sts	R/U
MC19	D	B2.5k, B2.1sts	A
NR8	4786	B2.8k, B2.1sts	A
MC20	D	B2.2k	R/U

Question	Key	Outcome	Cognitive Level
MC21	A	B2.3k, B2.1sts	A
MC22	C	B2.7k, B2.1sts	A
MC23	A	C1.3k, C1.3s	A
MC24	D	C1.3k, C1.4k, C1.3s, C1.1sts	R/U
NR9	*(see below)	C1.2k, C1.1sts	A
MC25	A	C1.6k, C1.3s	HMA
MC26	D	C2.2k	A
NR10	3142	C1.6k, C1.2s, C1.3s	HMA
MC27	C	C1.5k, C1.3s	A
MC28	B	C1.3k, C1.3s	A
NR11	3581	C1.7k, C2.1k, C2.2k, C2.1sts	A
MC29	D	C2.2k, C2.1s	R/U
MC30	A	D1.1k, D1.3sts	R/U
NR12	156 (any order)	D1.3k, D1.3s, D1.3sts	A
MC31	D	D1.4k, D1.3s, D1.3sts	A
MC32	B	D2.3k, D1.3s, D1.3sts	A
MC33	C	D2.3k, D2.3s	A
MC34	B	D1.3k	A
NR13	0.11	D2.3k, D2.3s	HMA
MC35	D	D1.7k	R/U
MC36	C	D1.8k, D1.1s	A
NR14	175	D2.2k, D1.2sts	A
MC37	A	D1.3k, D1.1s, D1.2sts	A
MC38	C	D1.6k, D1.2sts	A
MC39	C	C1.3k, C1.3s	R/U
MC40	A	C2.2k, C2.1s	R/U
MC41	B	D1.5k, D1.3sts	R/U
MC42	B	D2.2k, D1.3sts	A
NR15	2312, 3312	D1.7k, D1.8k	A
MC43	A	D1.8k	A
NR16	2519	D2.2k	A
MC44	D	D1.6k, D1.3s	A

***NR9:** 1527, 1525, 1535, 1538, 1546, 2515, 2535, 2538, 2546, 2715, 2735, 2738, 2746, 3515, 3525, 3527, 3546, 3815, 3825, 3827, 3846, 4615, 4625, 4627, 4635, 4638

Chemistry 30 Diploma Examination November 2018 Released Items

1. Which of the following statements makes a valid comparison between photosynthesis and cellular respiration?

A. Photosynthesis is an exothermic process and cellular respiration is an endothermic process.

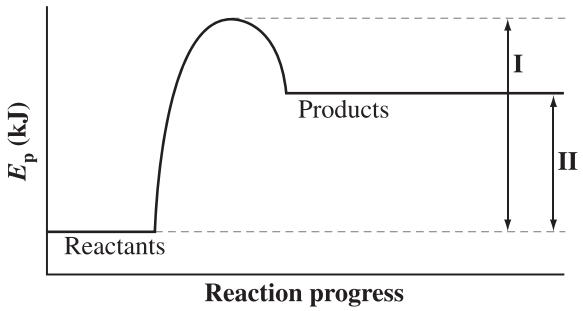
B. Both photosynthesis and cellular respiration store energy from the Sun in the form of glucose.

C. The products in the equation for photosynthesis are the reactants in the equation for cellular respiration.

D. The water in the photosynthesis reaction is in liquid form, while the water in the cellular respiration reaction is in gaseous form.

Use the following information to answer numerical-response question 1.

Enthalpy Diagram



Energy and Enthalpy Statements

1 The net enthalpy is represented by I.

2 The net enthalpy is represented by II.

3 The activation energy has a positive value.

4 The activation energy has a negative value.

5 The net enthalpy has a positive value.

6 The net enthalpy has a negative value.

Numerical Response

1. The statements that apply to the forward reaction represented by the enthalpy diagram above are numbered _____, _____, and _____.

(Record all **three digits** of your answer in **any order** in the numerical-response section on the answer sheet.)

Use the following information to answer questions 2 and 3 and numerical-response question 2.

Different cells use different enzymes to metabolize glucose, $C_6H_{12}O_6(aq)$, in the absence of oxygen. Muscle cells will convert glucose to lactic acid, $C_3H_6O_3(aq)$, as represented by the following equation.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{muscle cell enzymes}} 2\,C_3H_6O_3(aq) + 125.7\text{ kJ}$$

Yeast cells will convert glucose to ethanol, $C_2H_5OH(aq)$, and carbon dioxide, $CO_2(g)$, as represented by the following equation.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast cell enzymes}} 2\,C_2H_5OH(aq) + 2\,CO_2(g) + 79.9\text{ kJ}$$

A student dissolved 6.50 g of glucose into each of two identical polystyrene calorimeters containing 100.0 mL of water. She then added muscle cell enzymes to the contents of one calorimeter and yeast cell enzymes to the contents of the other, covered the calorimeters, and monitored the temperature change in each.

2. *The calorimeter that would have the greatest change in temperature would be the one containing enzymes from* ___***i***___ *cells. The manipulated variable in this experiment is the* ___***ii***___ *added to the contents of each calorimeter.*

The statements above are completed by the information in row

Row	***i***	***ii***
A.	muscle	mass of glucose
B.	muscle	type of enzyme
C.	yeast	mass of glucose
D.	yeast	type of enzyme

3. *In comparison to a reaction pathway without an enzyme, the activation energy for the reaction pathway provided by either enzyme will be* ___***i***___ *and the value of ΔH for the reaction will* ___***ii***___ .

The statement above is completed by the information in row

Row	*i*	*ii*
A.	higher	increase
B.	higher	be unchanged
C.	lower	increase
D.	lower	be unchanged

Use the following additional information to answer numerical-response question 2.

The student collected the following data during the experiment.

Mass of glucose	6.50 g
Mass of muscle cell enzymes	0.10 g
Volume of water in the calorimeter	100.0 mL
Initial temperature of calorimeter water	21.4 °C
Final temperature of calorimeter water	31.5 °C

Assume the specific heat capacity of the solution is the same as that of water.

Numerical Response

2. The experimental value for the molar enthalpy of reaction for glucose in this experiment is +/–_____ kJ/mol.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer questions 4 and 5 and numerical-response question 3.

Carbon dioxide gas can be captured and used to produce methanoic acid, as represented by the following equation.

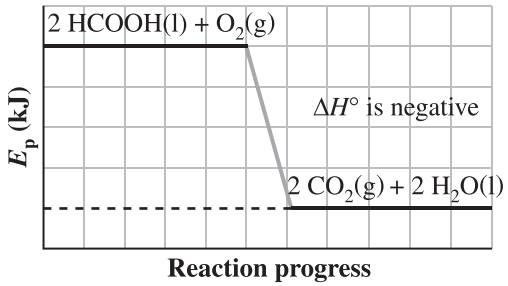
Equation I $CO_2(g) + H_2(g) \rightarrow HCOOH(l)$ $\Delta H = ?$

The methanoic acid, in the presence of a catalyst, can be used to produce electricity, as represented by the following equation.

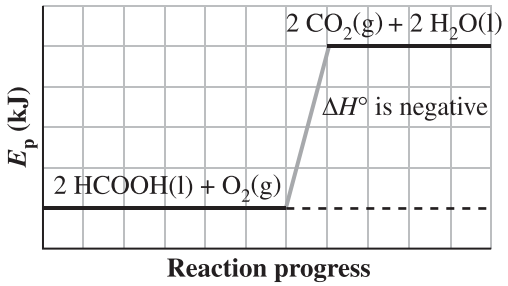
Equation II $2\,HCOOH(l) + O_2(g) \xrightarrow{\text{catalyst}} 2\,CO_2(g) + 2\,H_2O(l) + 508.6\,kJ$

4. An enthalpy diagram that could represent Equation II is

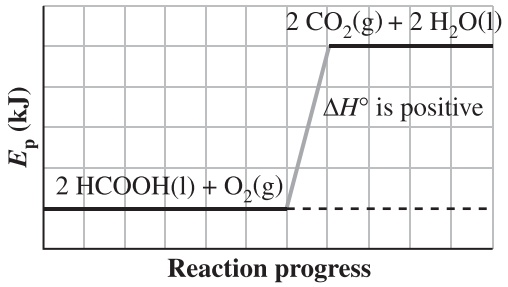
A.



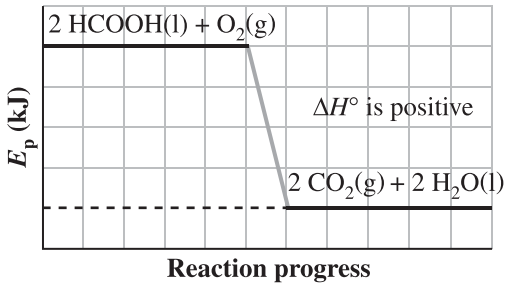
B.



C.



D.



5. When an enthalpy change of 200 kJ is observed in the reaction represented by Equation II, the mass of $CO_2(g)$ that will be produced is

A. 17.3 g

B. 34.6 g

C. 1.16×10^3 g

D. 2.31×10^3 g

Use the following additional information to answer numerical-response question 3.

Reaction Descriptions

1 The reaction is endothermic.

2 The reaction is exothermic.

3 During the reaction, energy is released to the surroundings.

4 During the reaction, energy is absorbed from the surroundings.

5 Energy would be a reactant if included as a term in the equation.

6 Energy would be a product if included as a term in the equation.

7 The potential energy of the reactants is greater than the potential energy of the products.

8 The potential energy of the reactants is less than the potential energy of the products.

Numerical Response

3. The reaction descriptions above that apply to Equation I are numbered _____, _____, _____, and _____.

(Record all **four digits** of your answer **in any order** in the numerical-response section on the answer sheet.)

Use the following information to answer numerical-response question 4 and questions 6 and 7.

Hydrogen cyanide gas, HCN(g), is used in the production of many plastics. This gas can be prepared by the reaction of methane, $CH_4(g)$, and ammonia, $NH_3(g)$, in the presence of a catalyst, as represented by the following equation.

$$CH_4(g) + NH_3(g) \xrightarrow{\text{catalyst}} HCN(g) + 3\,H_2(g) \qquad \Delta H^\circ = \textbf{?}$$

Relevant Equations

Equation I	$N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$	$\Delta H^\circ = -91.8$ kJ
Equation II	$C(s) + 2\,H_2(g) \rightarrow CH_4(g)$	$\Delta H^\circ = -74.6$ kJ
Equation III	$H_2(g) + 2\,C(s) + N_2(g) \rightarrow 2\,HCN(g)$	$\Delta H^\circ = +270.3$ kJ

Numerical Response

4. In Equation I, the molar enthalpy of reaction for $H_2(g)$ is +/–_____ kJ/mol.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

6. *In Equation II, methane contains* ___***i***___ *chemical potential energy than the reactants from which it was formed. This chemical potential energy originated from* ___***ii***___ .

The statements above are completed by the information in row

Row	*i*	*ii*
A.	less	the Sun
B.	less	fossil fuels
C.	more	the Sun
D.	more	fossil fuels

7. The enthalpy change for $CH_4(g) + NH_3(g) \xrightarrow{\text{catalyst}} HCN(g) + 3\,H_2(g)$ is

A. +14.7 kJ

B. +103.9 kJ

C. +255.7 kJ

D. +436.9 kJ

Use the following information to answer questions 8 and 9.

In the absence of oxygen, glucose, $C_6H_{12}O_6(aq)$, can undergo fermentation producing ethanol, $C_2H_5OH(l)$, and carbon dioxide, $CO_2(g)$, as represented by the following equation.

$$C_6H_{12}O_6(aq) \rightarrow 2\,C_2H_5OH(l) + 2\,CO_2(g)$$

Assume the value of $\Delta_f H°$ for $C_6H_{12}O_6(aq)$ is the same as the value of $\Delta_f H°$ for $C_6H_{12}O_6(s)$.

8. The enthalpy change associated with the fermentation reaction is

A. –1 342.2 kJ

B. –68.9 kJ

C. +594.0 kJ

D. +602.2 kJ

9. *In the fermentation reaction, ethanol is the product of* ___***i***___ *half-reaction, and carbon dioxide is the product of* ___***ii***___ *half-reaction.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	an oxidation	a reduction
B.	an oxidation	an oxidation
C.	a reduction	a reduction
D.	a reduction	an oxidation

Use the following information to answer question 10.

Reaction Equations

1 $H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$

2 $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

3 $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

4 $2\,NH_3(g) + \frac{7}{2}O_2(g) \rightarrow 2\,NO_2(g) + 3\,H_2O(g)$

10. Of the equations above, the redox reactions are numbered

A. 1 and 2

B. 1 and 4 only

C. 1, 3, and 4

D. 2 and 3

Use the following information to answer question 11.

Some groups of bacteria use hydrogen sulfide gas, $H_2S(g)$, for chemosynthesis instead of the water used in photosynthesis. This chemosynthesis process can be represented by the following equation.

$$6\,CO_2(g) + 12\,H_2S(g) \rightarrow C_6H_{12}O_6(aq) + 6\,H_2O(l) + 12\,S(s)$$

11. *During the reaction represented by the equation above, the hydrogen sulfide is the* ___***i***___ *agent and the sulfur undergoes* ___***ii***___ .

The statement above is completed by the information in row

Row	*i*	*ii*
A.	reducing	oxidation
B.	reducing	reduction
C.	oxidizing	oxidation
D.	oxidizing	reduction

Use the following information to answer numerical-response question 5 and question 12.

Several metals are used in the manufacture of permanent magnets. A student wanted to compare the relative strengths of some of these metals and their corresponding ions as oxidizing and reducing agents. He immersed a strip of each metal in an aqueous solution of a metallic ion and recorded the following observations.

Selected Observations

$Co^{2+}(aq) + Nd(s) \rightarrow Co(s) + Nd^{2+}(aq)$

$Y^{3+}(aq) + Nd(s) \rightarrow$ no evidence of reaction

$Sm^{2+}(aq) + Y(s) \rightarrow$ no evidence of reaction

Chemical Species

1	Co(s)	**5**	$Co^{2+}(aq)$
2	Nd(s)	**6**	$Nd^{2+}(aq)$
3	Sm(s)	**7**	$Sm^{2+}(aq)$
4	Y(s)	**8**	$Y^{3+}(aq)$

Numerical Response

5. The oxidizing agents, listed from **strongest** to **weakest**, are numbered

_____ , _____ , _____ , and _____ .
Strongest **Weakest**

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

12. An equation that represents a nonspontaneous reaction is

A. $2\ Y^{3+}(aq) + 3\ Sm(s) \rightarrow 2\ Y(s) + 3\ Sm^{2+}(aq)$

B. $3\ Nd^{2+}(aq) + 2\ Y(s) \rightarrow 3\ Nd(s) + 2\ Y^{3+}(aq)$

C. $Nd^{2+}(aq) + Co(s) \rightarrow Nd(s) + Co^{2+}(aq)$

D. $Co^{2+}(aq) + Sm(s) \rightarrow Co(s) + Sm^{2+}(aq)$

Numerical Response

6. The oxidation number for sulfur in

$SO_2(g)$ is +/– _____ (Record in the **first** column)

$SO_3(g)$ is +/– _____ (Record in the **second** column)

$H_2SO_3(aq)$ is +/– _____ (Record in the **third** column)

$H_2SO_4(aq)$ is +/– _____ (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer question 13.

Incomplete and Unbalanced Half-reaction Equation

$$Br_2(l) \rightarrow BrO_3^-(aq)$$

This incomplete half-reaction must be completed and balanced for it to represent the half-reaction of bromine in an acidic solution.

13. Which of the following rows identifies the lowest whole-number coefficients for $H_2O(l)$ and $H^+(aq)$ that are required to complete and balance the half-reaction equation above?

Row	$H_2O(l)$	$H^+(aq)$
A.	3	3
B.	3	6
C.	6	6
D.	6	12

Use the following information to answer questions 14 and 15.

Sulfur dioxide gas, $SO_2(g)$, in air contributes to the formation of acid rain. The concentration of $SO_2(g)$ in air can be determined by dissolving the $SO_2(g)$ in water and then titrating the solution produced with a standard solution of potassium permanganate, $KMnO_4(aq)$. The titration reaction can be represented by the following **unbalanced** equation.

$$\_\_SO_2(aq) + \_\_MnO_4^-(aq) + \_\_H_2O(l) \rightarrow \_\_SO_4^{2-}(aq) + \_\_Mn^{2+}(aq) + \_\_H^+(aq)$$

14. During the titration, a student would expect to observe

A. an increase in acidity

B. a decrease in solution volume

C. a decrease in the electrical conductivity

D. an increase in the intensity of the purple colour

15. A 150 mL sample of $SO_2(aq)$ required 31.5 mL of 0.0100 mol/L $KMnO_4(aq)$ to completely react. The concentration of $SO_2(aq)$ in the sample was

A. 0.840 mmol/L

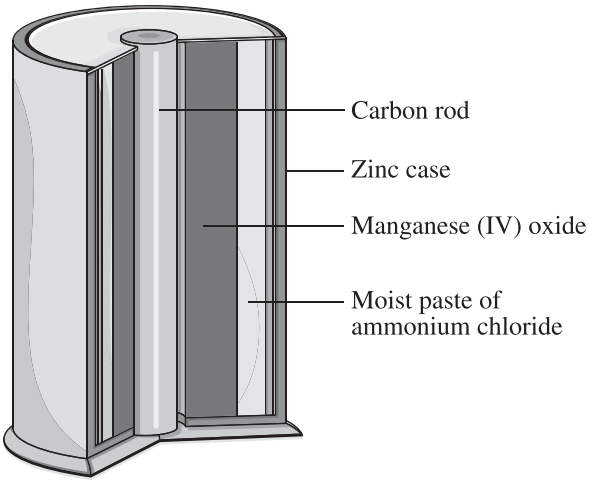
B. 2.10 mmol/L

C. 5.25 mmol/L

D. 118 mmol/L

Use the following information to answer questions 16 and 17 and numerical-response question 7.

Zinc–Carbon Cell



Half-Reactions in the Cell

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2\,e^-$$

$$2\,MnO_2(s) + 2\,NH_4^+(aq) + 2\,e^- \rightarrow Mn_2O_3(s) + 2\,NH_3(aq) + H_2O(l)$$

The value for the cell potential difference, E°_{cell}, is +1.50 V.

16. *A zinc–carbon cell is an example of* ___***i***___ *cell. The moist paste of ammonium chloride allows for the flow of* ___***ii***___ .

The statements above are completed by the information in row

Row	*i*	*ii*
A.	a voltaic	electrons
B.	a voltaic	ions
C.	an electrolytic	electrons
D.	an electrolytic	ions

17. *The cathode in the zinc–carbon cell is made of* ___***i***___ *and, when the cell is operating, the electrons will flow* ___***ii***___ .

The statement above is completed by the information in row

Row	*i*	*ii*
A.	zinc	from the anode to the cathode
B.	zinc	from the cathode to the anode
C.	carbon	from the anode to the cathode
D.	carbon	from the cathode to the anode

Numerical Response

7. The electrical potential, $E°$, for the half-reaction
$2\,MnO_2(s) + 2\,NH_4^+(aq) + 2\,e^- \rightarrow Mn_2O_3(s) + 2\,NH_3(aq) + H_2O(l)$ is +/–_____ V.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer questions 18 and 19 and numerical-response question 8.

The amount of ethanol, $C_2H_5OH(aq)$, in a person's breath can be measured in an electrochemical cell. The relevant half-reaction equations are given below.

Half-Reaction Equations

I $CH_3COOH(aq) + 4\,H^+(aq) + 4\,e^- \rightarrow C_2H_5OH(aq) + H_2O(l)$ $\quad E° = +0.58$ V

II $O_2(g) + 4\,H^+(aq) + 4\,e^- \rightarrow 2\,H_2O(l)$ $\quad E° = +1.23$ V

18. The half-reaction that occurs at the cathode is

A. $CH_3COOH(aq) + 4\,H^+(aq) + 4\,e^- \rightarrow C_2H_5OH(aq) + H_2O(l)$

B. $O_2(g) + 4\,H^+(aq) + 4\,e^- \rightarrow 2\,H_2O(l)$

C. $C_2H_5OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4\,H^+(aq) + 4\,e^-$

D. $2\,H_2O(l) \rightarrow O_2(g) + 4\,H^+(aq) + 4\,e^-$

19. If the reference half-cell were changed from the standard hydrogen half-cell to the standard cadmium half-cell, then the reduction potential for Equation I would become

A. −0.98 V

B. −0.18 V

C. +0.18 V

D. +0.98 V

Numerical Response

8. If a current of 4.00×10^{-3} A is maintained for 10.0 s in this electrochemical cell, then the mass of ethanol that reacted, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ g. The values of ***a***, ***b***, ***c***, and ***d*** are _____, _____, _____, and _____.
a ***b*** ***c*** ***d***

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

20. Which row identifies one characteristic of a voltaic cell **and** one characteristic of an electrolytic cell?

Row	Voltaic Cell	Electrolytic Cell
A.	E°_{cell} is less than 0	Spontaneous reaction
B.	Converts chemical energy to electrical energy	Moves anions toward the cathode
C.	Moves electrons toward the anode	Reduces the strongest oxidizing agent at the anode
D.	Requires a type of salt bridge	Requires an external power source

Use the following information to answer questions 21 and 22.

The silver from sunken treasure is gradually transformed to silver sulfide, $Ag_2S(s)$, by exposure to marine chemosynthetic bacteria. The $Ag_2S(s)$ forms a layer on the surface of an object. The layer of $Ag_2S(s)$ can be removed by electrolysis in a dilute solution of sodium hydroxide, NaOH(aq).

21. The half-reaction that the hydroxide ion $OH^-(aq)$ undergoes in this electrolysis is

A. $4\,OH^-(aq) \rightarrow 2\,H_2O(l) + O_2(g) + 4\,e^-$

B. $H_2(g) + 2\,OH^-(aq) \rightarrow 2\,H_2O(l) + 2\,e^-$

C. $2\,H_2O(l) + O_2(g) + 4\,e^- \rightarrow 4\,OH^-(aq)$

D. $2\,H_2O(l) + 2\,e^- \rightarrow H_2(g) + 2\,OH^-(aq)$

22. Which of the following metals will act spontaneously as reducing agents with silver iodide but **not** with silver sulfide?

A. Hg(l) and Cu(s)

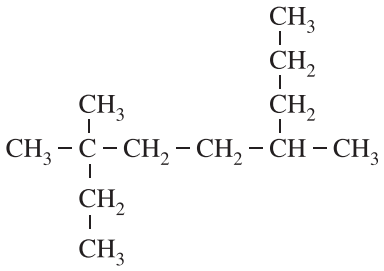
B. Cr(s) and Al(s)

C. Ni(s) and Co(s)

D. Au(s) and Mg(s)

Use the following information to answer question 23.

Branched Hydrocarbon



23. The parent chain of the molecule represented by the diagram above is based on

A. nonane

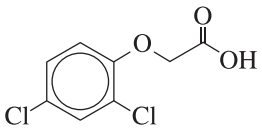
B. octane

C. heptane

D. hexane

Use the following information to answer question 24.

The herbicide 2,4-D is widely used for controlling broadleaf weeds. Its structure is shown in the line diagram below.



24. *The herbicide 2,4-D can be classified as an* ___***i***___ *organic compound with* ___***ii***___ *functional group.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	aliphatic	an ester
B.	aliphatic	a carboxylic acid
C.	aromatic	an ester
D.	aromatic	a carboxylic acid

Use the following information to answer numerical-response question 9.

Organic Compounds and Their Possible Uses

Organic Compound	Use
1 Octane	**5** A fuel for vehicles
2 Methane	**6** A food preservative
3 Methanol	**7** A fuel for home gas furnaces
4 Ethanoic acid	**8** An automobile antifreeze component

Numerical Response

9. Match the numbers of **two** of the organic compounds listed above with one of their possible uses. (There is more than one correct answer.)

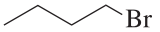
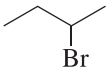
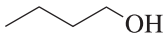
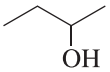
_____ (Record in the **first** column) is an organic compound used as _____. (Record in the **second** column)

_____ (Record in the **third** column) is an organic compound used as _____. (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer questions 25 and 26 and numerical-response question 10.

A student compiled the following data on a number of related organic compounds.

		Properties of Compounds	
Compound		**Boiling Point (°C)**	**Solubility in Water at 25 °C**
1		101.6	Insoluble
2		91.3	Insoluble
3		73.3	Insoluble
4		117.7	Soluble
5		99.5	More soluble
6		82.4	Most soluble

25. Which of the following conclusions is a valid interpretation of the data above?

A. Boiling point decreases as branching increases.

B. Boiling point increases as length of the parent chain decreases.

C. Boiling point decreases as the number of carbon atoms increases.

D. Boiling point increases as the functional group becomes less polar.

26. *Compound 2 can form when but-2-ene reacts with* ___***i***___ *in* ___***ii***___ *reaction.*

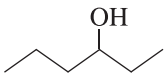
The statement above is completed by the information in row

Row	*i*	*ii*
A.	$Br_2(l)$	a substitution
B.	$Br_2(l)$	an addition
C.	HBr(g)	a substitution
D.	HBr(g)	an addition

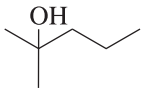
Use the following additional information to answer numerical-response question 10.

Other Organic Compounds

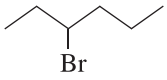
1



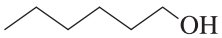
3



2



4



Numerical Response

10. Using the solubility data in the table on the previous page, arrange the organic compounds numbered above in order of **decreasing** solubility in water.

_____ , _____ , _____ , and _____

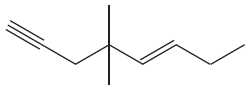
Most soluble **Least soluble**

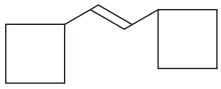
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

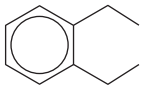
Use the following information to answer questions 27 and 28.

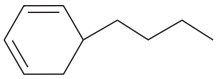
Myrcene, $C_{10}H_{16}(l)$, is an example of a fragrant hydrocarbon. Myrcene is an alkene with a number of double bonds in its structure. When myrcene is reacted with excess hydrogen, $H_2(g)$, in the presence of a platinum catalyst, a decane isomer, $C_{10}H_{22}(l)$, is produced.

27. Myrcene is **not** an isomer of

A. 

B. 

C. 

D. 

28. The number of carbon–carbon double bonds in myrcene is

A. 2

B. 3

C. 4

D. 6

Use the following information to answer numerical-response question 11.

In order to prepare chemicals for industry, many organic compounds must be separated from their natural mixtures.

Organic Material	Process	Type of Reaction
1 1-chloropropane	**5** Fractional distillation	**7** Elimination
2 1-chloropropene	**6** Solvent extraction	**8** Substitution
3 Crude oil		
4 Asphalt		

Numerical Response

11. Propane can be recovered from the organic material numbered _____ (Record in the **first** column) by the process numbered _____ (Record in the **second** column).

The propane reacts with chlorine gas in the presence of ultraviolet light in a type of reaction numbered _____ (Record in the **third** column) to produce hydrogen chloride gas and the organic material numbered _____ (Record in the **fourth** column).

(Record your answer in the numerical-response section on the answer sheet.)

---

29. Ethyl propanoate can be formed by the reaction of

A. propan-1-ol and ethane

B. propan-1-ol and ethanoic acid

C. ethanol and propane

D. ethanol and propanoic acid

Use the following information to answer questions 30 to 32 and numerical-response question 12.

The equilibrium equation shown below represents a reaction that produces hydrogen gas, $H_2(g)$, for use in the manufacture of some fertilizers.

$$CO_2(g) + CH_4(g) + \text{energy} \rightleftharpoons 2\,CO(g) + 2\,H_2(g)$$

30. Which of the following observations would **not** be an indication of a system that has reached equilibrium?

A. A constant mass

B. A constant pressure

C. A constant temperature

D. A constant number of gaseous molecules

Use the following additional information to answer numerical-response question 12.

Stresses

1 Add $H_2(g)$

2 Add $CO_2(g)$

3 Add a catalyst

4 Remove $CO(g)$

5 Remove $CH_4(g)$

6 Decrease the volume of the reaction container

Numerical Response

12. When applied to the equilibrium above, the stresses that would cause a shift toward the reactants are numbered _____, _____, and _____.

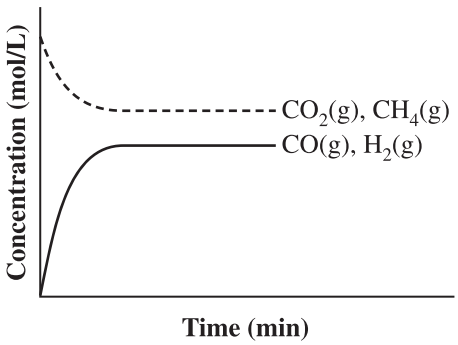
(Record all **three digits** of your answer **in any order** in the numerical-response section on the answer sheet.)

Use the following additional information to answer questions 31 and 32.

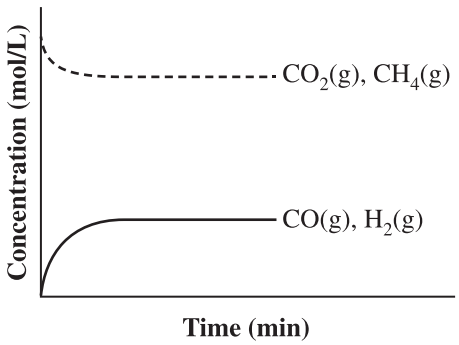
A technician put 1.0 mol of $CH_4(g)$ and 1.0 mol of $CO_2(g)$ in an empty 1.0 L reaction container. The container was sealed and the system was allowed to reach equilibrium at 1 200 K. At this temperature, the value of K_c is 3.3×10^{10}.

31. Which of the following sketches **best** represents the progress of the system as equilibrium is established?

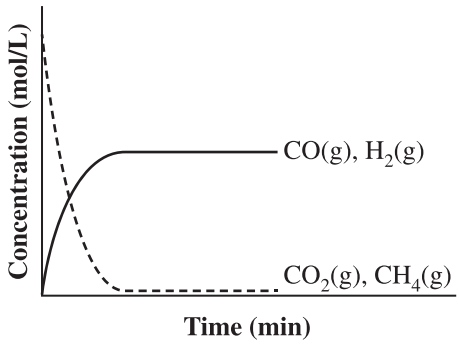
A.



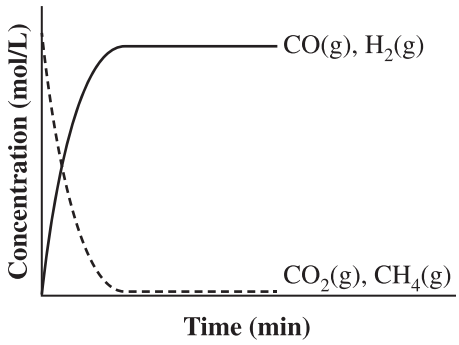
B.



C.



D.



32. In order to calculate the equilibrium concentrations, what equation, where x represents the change in concentration of $CH_4(g)$, could be used?

A. $3.3 \times 10^{10} = \dfrac{(2x)^2}{(1.0 - x)^2}$

B. $3.3 \times 10^{10} = \dfrac{(2x)^2(2x)^2}{(1.0 - x)^2}$

C. $3.3 \times 10^{10} = \dfrac{4x^2}{(1.0 - x)}$

D. $3.3 \times 10^{10} = \dfrac{x^2}{1.0^2}$

Use the following information to answer questions 33 and 34.

Methanol, $CH_3OH(g)$, is produced commercially by the catalyzed reaction of carbon monoxide, $CO(g)$, and hydrogen, $H_2(g)$, as represented by the following equation.

$$CO(g) + 2\,H_2(g) \underset{}{\overset{\text{catalyst}}{\rightleftharpoons}} CH_3OH(g) \qquad \Delta H = -90.5 \text{ kJ}$$

At equilibrium, the concentrations were measured as follows:

$$[CO(g)] = 0.75 \text{ mol/L}$$
$$[H_2(g)] = 1.25 \text{ mol/L}$$
$$[CH_3OH(g)] = 2.75 \text{ mol/L}$$

33. The value of the equilibrium constant, K_c, is

A. 0.34

B. 0.43

C. 2.3

D. 2.9

34. *Heating the equilibrium system represented by the equation above would shift the equilibrium toward the* ___***i***___ *, and the value of* K_c *would* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
A.	reactants	increase
B.	reactants	decrease
C.	products	increase
D.	products	decrease

Use the following information to answer numerical-response question 13.

Methane gas, $CH_4(g)$, can be produced in a laboratory by reacting carbon disulfide, $CS_2(g)$, and hydrogen gas, $H_2(g)$, as represented by the following equation.

$$CS_2(g) + 4\,H_2(g) \rightleftharpoons CH_4(g) + 2\,H_2S(g)$$

Initially, at a temperature of 90 °C, 0.18 mol/L $CS_2(g)$ and 0.31 mol/L $H_2(g)$ are present in a closed container. When equilibrium is established, 0.13 mol/L $CS_2(g)$ is present.

Numerical Response

13. The concentration of hydrogen gas present in the container at equilibrium is _____ mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer question 35.

Chemical Species

I $H_3BO_3(aq)$

II $H_2BO_3^-(aq)$

III $HBO_3^{2-}(aq)$

IV $BO_3^{3-}(aq)$

35. *In the list of chemical species above, $H_2BO_3^-(aq)$ and ____**i**____ would form a conjugate acid–base pair, and the amphiprotic species are ____**ii**____ .*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	III only	II, III, and IV
B.	III only	II and III only
C.	I or III	II, III, and IV
D.	I or III	II and III only

Use the following information to answer question 36.

A student prepared two solutions with the same pH and added chlorophenol red indicator to each solution. The student recorded the following information.

Before Addition of HCl(aq)

Solution	Solution Content	Colour	pH
I	$H_2S(aq)$	Orange	6.6
II	$H_2S(aq)$ and $HS^-(aq)$	Orange	6.6

The student then added a small amount of HCl(aq) to each solution.

After Addition of HCl(aq)

Solution	Solution Content	Colour	pH
I	$H_2S(aq)$	**?**	**?**
II	$H_2S(aq)$ and $HS^-(aq)$	**?**	**?**

36. Which of the following rows identifies the observed colour and the observed effect on the pH **after** the addition of a small amount of HCl(aq) to each of the two solutions?

	Solution I		Solution II	
Row	**Colour**	**Effect on pH**	**Colour**	**Effect on pH**
A.	Orange	No change	Red	Increase
B.	Orange	No change	Yellow	Decrease
C.	Yellow	Decrease	Orange	No change
D.	Red	Increase	Orange	No change

Use the following information to answer numerical-response question 14 and questions 37 and 38.

Potassium sorbate, $C_5H_7COOK(aq)$, is used as a preservative in beverages to inhibit the growth of mould. The equilibrium formed when the sorbate ion, $C_5H_7COO^-(aq)$, reacts with water can be represented by the following equation.

$$C_5H_7COO^-(aq) + H_2O(l) \rightleftharpoons C_5H_7COOH(aq) + OH^-(aq) \qquad K_b = 5.8 \times 10^{-10}$$

Although the potassium sorbate is added to the beverage, it is the sorbic acid, $C_5H_7COOH(aq)$, that inhibits the growth of mould.

Numerical Response

14. The value of K_a for sorbic acid, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{c}}$. The values of ***a***, ***b***, and ***c*** are _____, _____, and _____.
a ***b*** ***c***

(Record all **three digits** of your answer in the numerical-response section on the answer sheet.)

37. The amount of sorbic acid present could be increased by

A. adding HCl(aq)

B. adding NaOH(aq)

C. removing $H_2O(l)$

D. removing $C_5H_7COO^-(aq)$

38. When reacted with $C_5H_7COOK(aq)$, an acid that would produce an equilibrium that favours the reactants is

A. HCOOH(aq)

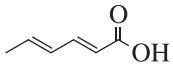
B. $C_6H_5COOH(aq)$

C. $C_2H_5COOH(aq)$

D. $C_2H_5OCOOH(aq)$

Use the following information to answer questions 39 and 40.

The structure of sorbic acid can be represented by the following line diagram.



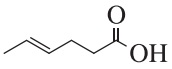
39. *Sorbic acid is classified as* ___***i***___ *compound, and the rate of its reaction with bromine, $Br_2(aq)$, is predicted to be* ___***ii***___ .

The statement above is completed by the information in row

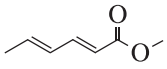
Row	***i***	***ii***
A.	a saturated	fast
B.	a saturated	slow
C.	an unsaturated	fast
D.	an unsaturated	slow

Use the following additional information to answer question 40.

Some moulds detoxify sorbic acid by converting it into other compounds. Two of these compounds are represented by the following line diagrams.



Compound I



Compound II

40. *Compound I can be produced from sorbic acid in* ___***i***___ *reaction, and Compound II can be produced from sorbic acid in an* ___***ii***___ *reaction.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	an addition	esterification
B.	an addition	elimination
C.	a substitution	esterification
D.	a substitution	elimination

Use the following information to answer questions 41 and 42.

Codeine, $C_{18}H_{21}NO_3(aq)$, a sedative and analgesic, is present in several types of painkillers. Codeine is a weak base that can react with water, as represented by the following equation.

$$C_{18}H_{21}NO_3(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + C_{18}H_{21}NO_3H^+(aq) \qquad K_b = 1.62 \times 10^{-6}$$

The equilibrium law expression for this equilibrium is

$$K_b = \frac{[OH^-(aq)][C_{18}H_{21}NO_3H^+(aq)]}{[C_{18}H_{21}NO_3(aq)]}$$

41. In the reaction represented above, the species that act as Brønsted–Lowry acids are

A. $C_{18}H_{21}NO_3(aq)$ and $C_{18}H_{21}NO_3H^+(aq)$

B. $H_2O(l)$ and $C_{18}H_{21}NO_3H^+(aq)$

C. $C_{18}H_{21}NO_3(aq)$ and $OH^-(aq)$

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

42. A 0.100 mol/L solution of codeine, $C_{18}H_{21}NO_3(aq)$, will have a $[OH^-(aq)]$ of

A. 1.27×10^{-3} mol/L

B. 4.02×10^{-4} mol/L

C. 1.62×10^{-6} mol/L

D. 1.62×10^{-7} mol/L

Use the following information to answer numerical-response question 15.

Species and Ionization Constants

1	$C_3H_5O(COOH)_3(aq)$	$K_a = 7.4 \times 10^{-3}$
2	$C_3H_5O(COOH)_2COO^-(aq)$	$K_a = 1.7 \times 10^{-5}$
3	$C_3H_5OCOOH(COO)_2^{2-}(aq)$	$K_a = 4.0 \times 10^{-7}$

Numerical Response

15. Match the species numbered above with their descriptions given below. (There is more than one correct answer.)

The species that is both polyprotic and amphiprotic is _____. (Record in the **first** column)

The species that is the conjugate base of $C_3H_5O(COOH)_2COO^-(aq)$ is _____. (Record in the **second** column)

The species with the weakest conjugate base is _____. (Record in the **third** column)

The species that will form a buffer when mixed with an equal amount of $C_3H_5O(COOH)_3(aq)$ is _____. (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer question 43.

Limestone rocks, $CaCO_3(s)$, present on the sea floor react with seawater to establish the $CO_3^{2-}(aq)$–$HCO_3^-(aq)$ buffer system on the sea floor.

43. *The equation that represents the reaction of $H_3O^+(aq)$ with the buffer on the sea floor is* ___***i***___ *. The effect of the buffer is to* ___***ii***___ *the pH of the seawater.*

The statements above are completed by the information in row

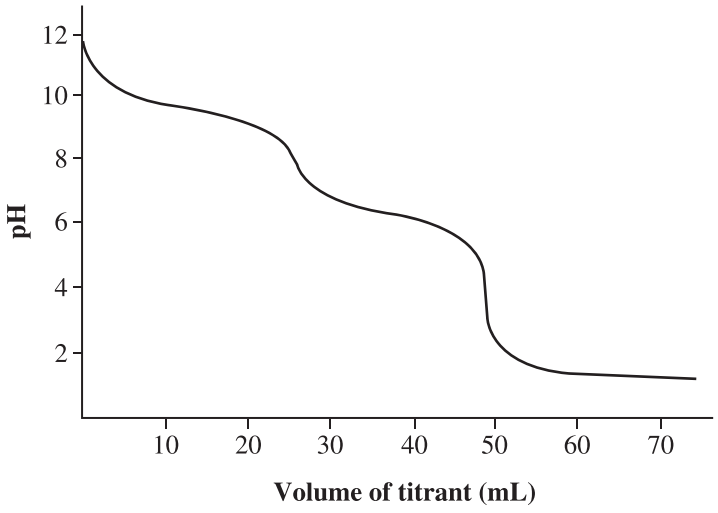
Row	*i*	*ii*
A.	$CO_3^{2-}(aq) + H_3O^+(aq) \rightleftharpoons HCO_3^-(aq) + H_2O(l)$	maintain
B.	$CO_3^{2-}(aq) + H_3O^+(aq) \rightleftharpoons HCO_3^-(aq) + H_2O(l)$	decrease
C.	$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(l)$	maintain
D.	$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(l)$	decrease

Numerical Response

16. A sample of rain was collected and the pH was measured to be 5.400. The $[OH^-(aq)]$ in the sample of rain, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ mol/L. The values of ***a***, ***b***, ***c***, and ***d*** are _____, _____, _____, and _____.
a ***b*** ***c*** ***d***

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following information to answer question 44.



44. *In the titration represented by the graph above, the titrant that is added to the solution is* ___***i***___ *, and the sample is* ___***ii***___ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	a base	monoprotic
B.	a base	polyprotic
C.	an acid	monoprotic
D.	an acid	polyprotic