

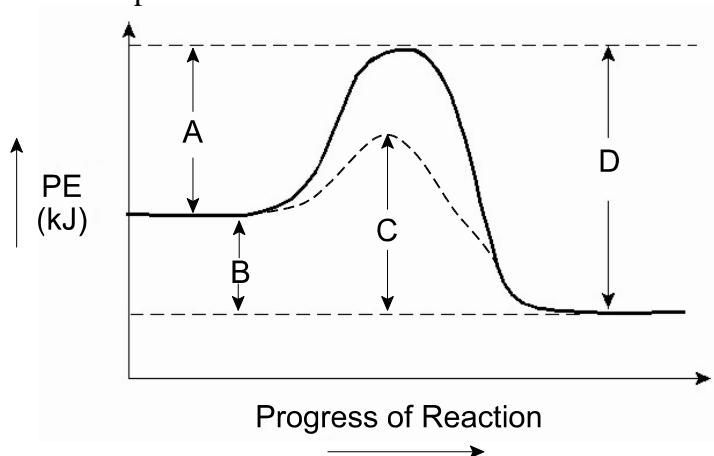
**PART I**  
**Total Value: 50%**

**Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided.**

1. According to collision theory, which is true about reactants when a chemical reaction occurs?

- (A) They acquire the activation energy.
- (B) They are gases.
- (C) They are heated.
- (D) They have more PE than products.

2. Which letter below represents the heat of reaction?



- (A) A
- (B) B
- (C) C
- (D) D

3. Which best indicates the energy as reactants collide and form an activated complex?

	Potential Energy	Kinetic Energy
(A)	decreases	decreases
(B)	decreases	remains constant
(C)	increases	decreases
(D)	increases	remains constant

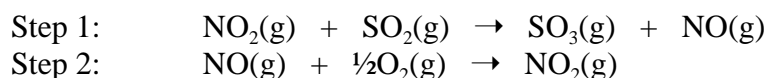
4. Which factor explains why coal dust is explosive?

- (A) concentration
- (B) pressure
- (C) surface area
- (D) temperature

5. Which reaction occurs fastest at room temperature?

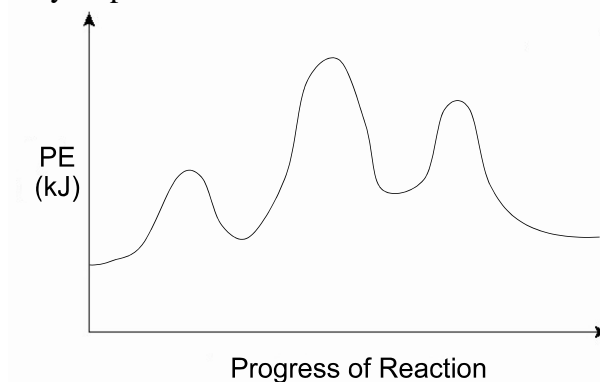
- (A)  $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\ell)$
- (B)  $2 \text{Ag}^+(\text{aq}) + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Ag}_2\text{CrO}_4(\text{s})$
- (C)  $\text{Pb}(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{PbCl}_2(\text{s}) + \text{H}_2(\text{g})$
- (D)  $\text{CH}_4(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g})$

6. Which is the catalyst in the reaction mechanism below?



- (A)  $\text{NO}(\text{g})$
- (B)  $\text{NO}_2(\text{g})$
- (C)  $\text{O}_2(\text{g})$
- (D)  $\text{SO}_2(\text{g})$

7. How many elementary steps are in the mechanism illustrated below?



- (A) 1
- (B) 2
- (C) 3
- (D) 4

8. Which are necessary to establish a dynamic equilibrium?

- (A) a changing concentration and a closed system
- (B) a constant temperature and an open system
- (C) an irreversible reaction and an open system
- (D) a reversible reaction and a closed system

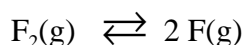
9. The equilibrium below is established in a rigid 1.0 L container.



If some  $\text{CH}_4(\text{g})$  is added to the system, what happens to the concentration of  $\text{CS}_2(\text{g})$  and the value of  $K$ ?

	[ $\text{CS}_2$ ]	$K$
(A)	decrease	constant
(B)	decrease	increase
(C)	increase	constant
(D)	increase	increase

10. If  $[\text{F}_2] = 1.0 \times 10^{-2} \text{ mol/L}$  and  $[\text{F}] = 3.0 \times 10^{-4} \text{ mol/L}$  in the equilibrium below, what is the value of the equilibrium constant?



- (A)  $9.0 \times 10^{-6}$
- (B)  $6.0 \times 10^{-2}$
- (C)  $3.0 \times 10^{-2}$
- (D)  $1.1 \times 10^5$

11. Which is the equilibrium expression for the system below?



(A) 
$$K = \frac{[\text{HF}]^2}{[\text{H}_2\text{O}] [\text{CO}_2]}$$

(B) 
$$K = \frac{[\text{H}_2\text{O}] [\text{CO}_2]}{[\text{HF}]^2}$$

(C) 
$$K = \frac{[\text{CaCO}_3][\text{HF}]^2}{[\text{CaF}_2][\text{H}_2\text{O}] [\text{CO}_2]}$$

(D) 
$$K = \frac{[\text{CaF}_2][\text{H}_2\text{O}] [\text{CO}_2]}{[\text{CaCO}_3][\text{HF}]^2}$$

12. Which K value indicates a reaction in which products are most favoured?

(A)  $1.0 \times 10^{-2}$

(B)  $1.0 \times 10^{-1}$

(C)  $1.0 \times 10^1$

(D)  $1.0 \times 10^2$

13. Which describes an Arrhenius base?

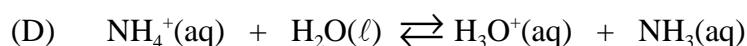
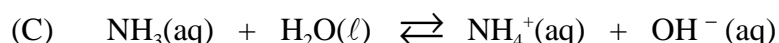
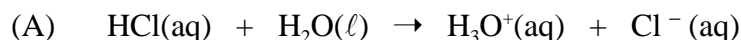
(A) donates  $\text{H}^+$  ions

(B) donates  $\text{OH}^-$  ions

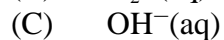
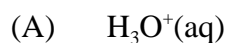
(C) produces  $\text{H}^+$  ions in aqueous solution

(D) produces  $\text{OH}^-$  ions in aqueous solution

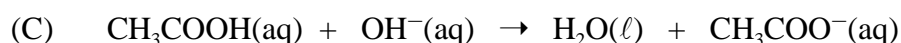
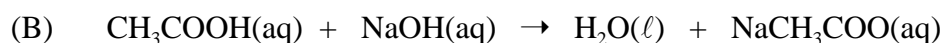
14. In which reaction is water behaving as a Brønsted-Lowry acid?



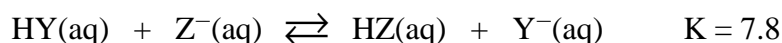
15. Which is the conjugate acid of  $\text{HS}^-(\text{aq})$ ?



16. Which is the net ionic equation for the neutralization of  $\text{CH}_3\text{COOH}(\text{aq})$  with  $\text{NaOH}(\text{aq})$ ?



17. Which is the strongest acid and strongest base in the equilibrium below?



	Strongest acid	Strongest base
(A)	HY	$\text{Y}^{-}$
(B)	HY	$\text{Z}^{-}$
(C)	HZ	$\text{Y}^{-}$
(D)	HZ	$\text{Z}^{-}$

18. According to Brønsted-Lowry theory, which best represents the self-ionization of water?

- (A)  $\text{H}_2\text{O}(\ell) \rightarrow 2 \text{H}^{+}(\text{aq}) + \text{O}^{2-}(\text{aq})$   
(B)  $\text{H}_2\text{O}(\ell) \rightarrow \text{H}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$   
(C)  $2 \text{H}_2\text{O}(\ell) \rightarrow \text{H}_3\text{O}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$   
(D)  $2 \text{H}_2\text{O}(\ell) \rightarrow 2 \text{H}_2(\text{g}) + \text{O}_2(\text{g})$

19. Why is the pH of 0.10 mol/L  $\text{H}_3\text{PO}_4(\text{aq})$  higher than the pH of 0.10 mol/L  $\text{HCl}(\text{aq})$ ?

- (A)  $\text{HCl}(\text{aq})$  ionizes to a greater extent.  
(B)  $\text{HCl}(\text{aq})$  is a weaker acid.  
(C)  $\text{H}_3\text{PO}_4(\text{aq})$  has more hydrogen atoms.  
(D)  $\text{H}_3\text{PO}_4(\text{aq})$  is amphoteric in water.

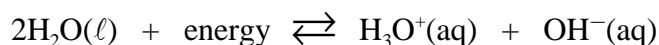
20. What is the pOH of 0.050 mol/L  $\text{NaOH}(\text{aq})$  at 25°C?

- (A) 1.00  
(B) 1.30  
(C) 12.70  
(D) 13.00

21. What is the  $[\text{H}_3\text{O}^{+}]$  of a solution with  $\text{pH} = 2.81$ ?

- (A)  $6.5 \times 10^{-12} \text{ mol/L}$   
(B)  $1.5 \times 10^{-3} \text{ mol/L}$   
(C)  $6.5 \times 10^2 \text{ mol/L}$   
(D)  $1.5 \times 10^{11} \text{ mol/L}$

22. Which will cause  $[\text{H}_3\text{O}^{+}]$  to decrease and  $K_w$  to remain constant for the equilibrium below?



- (A) adding a strong acid  
(B) adding a strong base  
(C) decreasing temperature  
(D) increasing temperature

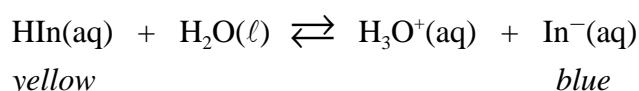
23. Which pair represents a possible buffer?

- (A)  $\text{HCl}(\text{aq})$  and  $\text{Cl}^{-}(\text{aq})$   
(B)  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$   
(C)  $\text{H}_2\text{CO}_3(\text{aq})$  and  $\text{HCO}_3^{-}(\text{aq})$   
(D)  $\text{H}_2\text{CO}_3(\text{aq})$  and  $\text{NH}_3(\text{aq})$

24. The pH values of 0.10 mol/L solutions of four unknown acids are given below. Which conjugate base has the lowest  $K_b$ ?

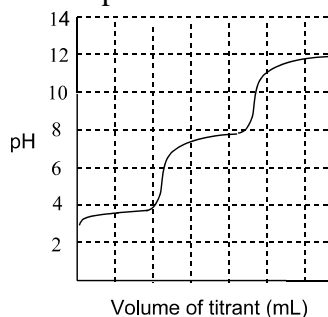
Acid	pH
HA(aq)	4.9
HB(aq)	6.4
HC(aq)	5.2
HD(aq)	3.6

- (A)  $A^-(aq)$   
 (B)  $B^-(aq)$   
 (C)  $C^-(aq)$   
 (D)  $D^-(aq)$
25. What occurs to the indicator equilibrium below when the indicator, HIn, is added to 0.10 mol/L HCl(aq)?



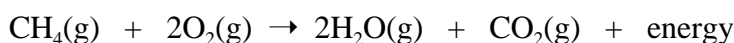
	Equilibrium Shift	Colour
(A)	left	blue
(B)	left	yellow
(C)	right	blue
(D)	right	yellow

26. Which is used in a titration to determine the concentration of an acid or base?
- (A) buffer  
 (B) pipette solution  
 (C) standard solution  
 (D) thermometer
27. If the initial pH of a solution was 11.2 and the pH at the equivalence point was 6.3, which pair was titrated?
- (A)  $\text{CH}_3\text{COOH(aq)}$  with  $\text{NaOH(aq)}$   
 (B)  $\text{HCl(aq)}$  with  $\text{NH}_3(\text{aq})$   
 (C)  $\text{NaOH(aq)}$  with  $\text{CH}_3\text{COOH(aq)}$   
 (D)  $\text{NH}_3(\text{aq})$  with  $\text{HCl(aq)}$
28. Which was most likely titrated to produce the curve below?



- (A)  $\text{CH}_3\text{COOH(aq)}$   
 (B)  $\text{H}_2\text{CO}_3(\text{aq})$   
 (C)  $\text{K}_2\text{SO}_3(\text{aq})$   
 (D)  $\text{Na}_3\text{PO}_4(\text{aq})$

29. Which best defines the specific heat capacity of a substance?
- (A) the energy required to raise the temperature of 1.0 g of a substance 1.0 °C  
 (B) the energy required to raise the temperature of 1.0 g of a substance 100.0 °C  
 (C) the energy required to raise the temperature of 1.0 mol of a substance 1.0 °C  
 (D) the energy required to raise the temperature of 1.0 mol of a substance 100.0 °C
30. If 23.9 g of an unknown metal requires 343 J of energy to change its temperature from 24.5 °C to 85.0 °C, what is the specific heat capacity of the metal?
- (A) 0.237 J/g · °C  
 (B) 0.568 J/g · °C  
 (C) 4.22 J/g · °C  
 (D) 868 J/g · °C
31. A substance undergoes a change that causes the temperature of its surroundings to increase but the temperature of the substance remains the same. Which best explains what happens to the substance?
- (A) kinetic energy decreases  
 (B) melts at its freezing point  
 (C) potential energy decreases  
 (D) vaporizes at its boiling point
32. Which best indicates what happens when CH<sub>4</sub>(g) burns according to the reaction below?



	Energy	ΔH
(A)	absorbed	negative
(B)	absorbed	positive
(C)	released	negative
(D)	released	positive

33. For the reaction below, what is the molar heat of formation of H<sub>2</sub>O(l)?
- $$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + 571.6\text{ kJ}$$
- (A) -571.6 kJ  
 (B) -285.8 kJ  
 (C) +285.8 kJ  
 (D) +571.6 kJ
34. What is the symbol for the enthalpy change that occurs when a substance changes from solid to liquid, under standard conditions?
- (A) ΔH<sup>o</sup><sub>cond</sub>  
 (B) ΔH<sup>o</sup><sub>fus</sub>  
 (C) ΔH<sup>o</sup><sub>soln</sub>  
 (D) ΔH<sup>o</sup><sub>vap</sub>
35. How much energy is absorbed when 10.0 g of water vaporizes at 100.0 °C?
- (A) 4.07 kJ  
 (B) 22.6 kJ  
 (C) 40.7 kJ  
 (D) 73.3 kJ

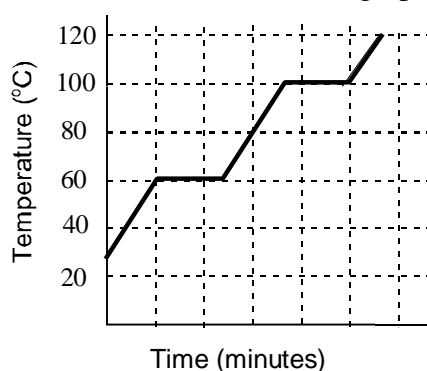
36. Which is the correct order of energy changes from greatest to least?

*greatest*  $\longrightarrow$  *least*

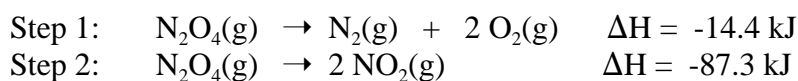
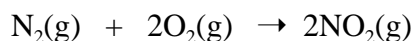
- (A) chemical  $\rightarrow$  nuclear  $\rightarrow$  physical  
(B) chemical  $\rightarrow$  physical  $\rightarrow$  nuclear  
(C) nuclear  $\rightarrow$  chemical  $\rightarrow$  physical  
(D) nuclear  $\rightarrow$  physical  $\rightarrow$  chemical
37. What is the fuel value of a 2.00 g sample of peanut butter that produces 45.24 kJ of energy?

- (A) 0.0442 kJ/g  
(B) 22.6 kJ/g  
(C) 43.2 kJ/g  
(D) 90.5 kJ/g

38. What is the melting point of the substance in the graph below?



- (A) 30 °C  
(B) 60 °C  
(C) 100 °C  
(D) 120 °C
39. Using the thermochemical equations given, what is the enthalpy of the reaction below?



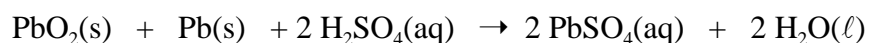
- (A) -101.7 kJ  
(B) -72.9 kJ  
(C) 72.9 kJ  
(D) 101.7 kJ
40. If the molar heat of formation for  $\text{CH}_3\text{OH}(\ell)$  is  $-239.2 \text{ kJ/mol}$ , what is the molar heat of formation for  $\text{CO}(\text{g})$ ?



- (A) -367.9 kJ/mol  
(B) -110.5 kJ/mol  
(C) 110.5 kJ/mol  
(D) 367.9 kJ/mol

41. Which is true for a reducing agent?
- (A) it is oxidized as it gains electrons  
 (B) it is oxidized as it loses electrons  
 (C) it is reduced as it gains electrons  
 (D) it is reduced as it loses electrons
42. What happens to a substance when its oxidation number increases by two?
- (A) it is oxidized and gains 2 electrons  
 (B) it is oxidized and loses 2 electrons  
 (C) it is reduced and gains 2 electrons  
 (D) it is reduced and loses 2 electrons
43. What is the oxidation number of S in  $\text{Na}_2\text{CrO}_4$ ?
- (A) - 2  
 (B) + 2  
 (C) + 4  
 (D) + 6
44. Which is produced by the reduction of  $\text{NO}_2$ ?
- (A) NO  
 (B)  $\text{N}_2\text{O}_4$   
 (C)  $\text{N}_2\text{O}_5$   
 (D)  $\text{HNO}_3$

45. What is the balanced reduction half-reaction for the reaction below?

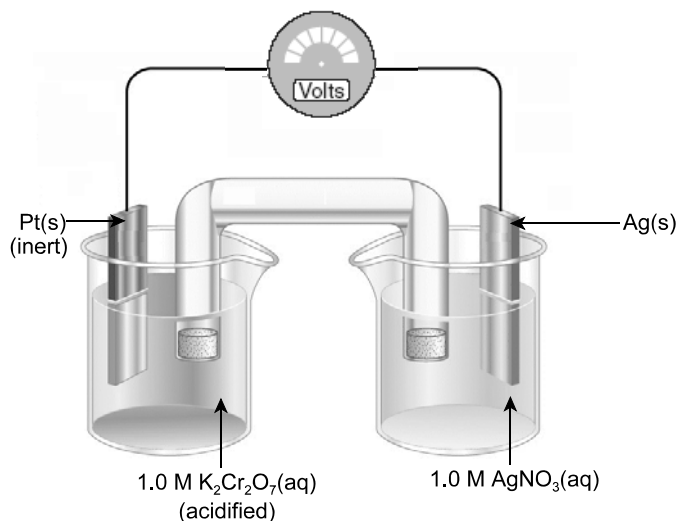


- (A)  $\text{Pb}(\text{s}) \rightarrow \text{Pb}^{2+}(\text{aq}) + 2 \text{e}^-$   
 (B)  $\text{Pb}(\text{s}) + 2 \text{e}^- \rightarrow \text{Pb}^{2+}(\text{aq})$   
 (C)  $\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) \rightarrow \text{Pb}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\ell) + 2 \text{e}^-$   
 (D)  $\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{Pb}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\ell)$
46. Which indicates a functioning electrochemical cell?

	Type of Reaction	Cell Potential
(A)	non-spontaneous	negative
(B)	non-spontaneous	positive
(C)	spontaneous	negative
(D)	spontaneous	positive

47. Which 1.0 mol/L salt solution would combine with  $\text{Mg}(\text{s})$  to give a voltaic cell with the highest voltage?
- (A)  $\text{Al}^{3+}(\text{aq})$   
 (B)  $\text{Cu}^{2+}(\text{aq})$   
 (C)  $\text{Fe}^{2+}(\text{aq})$   
 (D)  $\text{Zn}^{2+}(\text{aq})$

48. Which best describes the cell below?



	Type of cell	Standard cell potential
(A)	electrolytic	-0.53
(B)	electrolytic	0.53
(C)	galvanic	-0.53
(D)	galvanic	0.53

49.  $\text{Tl}^+$  reacts spontaneously with Be but not with Co. What is the order of ions in terms of their strength as oxidizing agents?

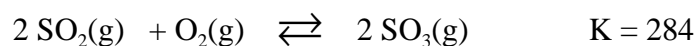
*strongest*  $\longrightarrow$  *weakest*

- (A)  $\text{Be}^{2+} > \text{Co}^{2+} > \text{Tl}^+$   
 (B)  $\text{Be}^{2+} > \text{Tl}^+ > \text{Co}^{2+}$   
 (C)  $\text{Co}^{2+} > \text{Be}^{2+} > \text{Tl}^+$   
 (D)  $\text{Co}^{2+} > \text{Tl}^+ > \text{Be}^{2+}$
50. Which is a major difference between a fuel cell and a combustion engine?
- (A) A combustion engine uses oxygen.  
 (B) A combustion engine produces water.  
 (C) A fuel cell is less efficient.  
 (D) A fuel cell produces electricity.



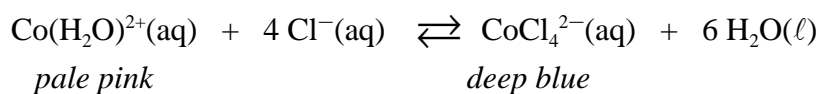
**Value**

2% 51.(c) At 1000 K, sulfur dioxide is converted into sulfur trioxide, as shown below.



If  $[\text{SO}_2] = 0.0150 \text{ mol/L}$ ,  $[\text{O}_2] = 0.0250 \text{ mol/L}$ , and  $[\text{SO}_3] = 0.0400 \text{ mol/L}$ , is the mixture at equilibrium? Justify your answer.

4% (d) The equilibrium below was established under constant temperature conditions.



(i) Explain what color change would occur if  $\text{AgNO}_3$  was added to the system, producing a precipitate.

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(ii) When the equilibrium is placed in an ice bath it turns pale pink. Is  $\Delta H$  for the forward reaction positive or negative? Justify your answer.

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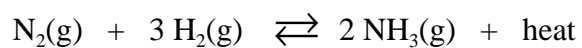
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**Value**

- 2% 51.(e) Explain what happens to the value of  $K$  in the equilibrium below when the temperature of the system is increased.



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- 4% 52.(a) Calculate the pH of a 0.15 mol/L solution of  $\text{HCN}(\text{aq})$  if  $K_a$  is  $6.2 \times 10^{-10}$ .

- 2% (b) Determine the Brønsted-Lowry acid-base neutralization reaction that occurs when  $\text{CH}_3\text{COOH}(\text{aq})$  is added to  $\text{Na}_2\text{SO}_3(\text{aq})$ . Indicate which side of the reaction is favoured.

**Value**

2% 52.(c) A cup of herbal tea turns from red to pink when a slice of lemon is added to it. Drops of tea remaining in the cup turn purple as the cup is being washed with soapy water. What causes the colour changes observed?

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4% (d) What is the pH of a solution formed by mixing 30.0 mL of 0.100 mol/L KOH with 70.0 mL of 0.200 mol/L HCl(aq)?

**Value**

- 2% 52.(e) Samples of hydrochloric acid, of unknown concentration, were titrated with a solution of sodium carbonate. The flasks were rinsed with a sodium carbonate stock solution before the samples of hydrochloric acid were added. Explain what effect this would have on the calculated concentration of acid.

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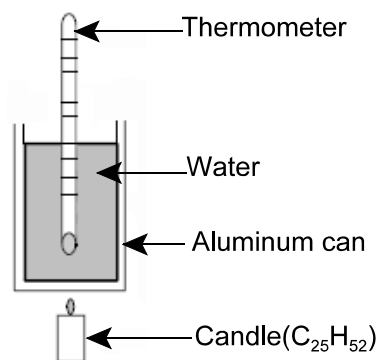
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- 5% 53.(a) In order to determine the molar heat of combustion of candle wax,  $C_{25}H_{52}(s)$ , water is heated in an aluminum can by a candle. The following results were recorded.

Mass of water	100.0 g
Mass of aluminum can	15.0 g
Specific heat capacity of $H_2O(l)$	4.184 J/g°C
Specific heat capacity of Al(s)	0.900 J/g°C
Initial temperature of $H_2O(l)$ and Al(s)	22.0 °C
Final temperature of $H_2O(l)$ and Al(s)	26.5 °C
Original mass of candle ( $C_{25}H_{52}$ )	10.62 g
Final mass of candle ( $C_{25}H_{52}$ )	10.32 g



If the heat produced from the candle was absorbed by the water and the aluminum can, what is the molar heat of combustion of the candle wax?

**Value**

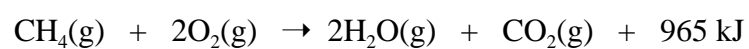
2% 53.(b) How many moles of methanol must burn to raise the temperature of 100.0 g of aluminum by 80.0 °C? Assume all heat is absorbed by the aluminum,  $c_{\text{Al}} = 0.900 \text{ J/g} \cdot ^\circ\text{C}$ , and the molar heat of combustion of methanol,  $\text{CH}_3\text{OH}(\ell)$ , is -239 kJ/mol.

3% (c) A 20.0 g sample of  $\text{NaCl}(\text{s})$ , at 801.0 °C, is heated to 1000.0 °C. Given the information below, calculate the total energy required to heat the sample.

Specific heat capacity of $\text{NaCl}(\text{s})$	1.23 J/g°C
Specific heat capacity of $\text{NaCl}(\ell)$	1.10 J/g°C
$\Delta H_{\text{fus}}$ of $\text{NaCl}(\text{s})$	28.0 kJ/mol
melting point of $\text{NaCl}(\text{s})$	801.0 °C

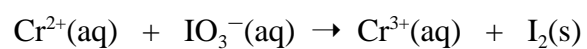
**Value**

3% 53.(d) Given the data below, calculate the energy required to break the C-H bond.



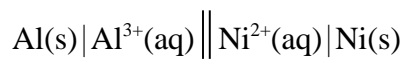
Bond	Bond Energy (kJ/mol)
H - O	460
C=O	745
O=O	498

3% 54.(a) Balance the redox reaction below under acidic conditions.



**Value**

3% 54.(b) Refer to the galvanic cell below to answer the following questions.



(i) What is the overall cell reaction and cell voltage? Show workings.

(ii) Give two reasons why the cell voltage determined experimentally was less than the calculated value in (i).

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4% (c) The titanium cathode in an electrolytic cell increases in mass by 2.35 g in 36.5 min at a current of 6.50 A. What is the charge on the titanium ion? Show workings.