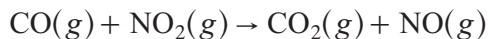
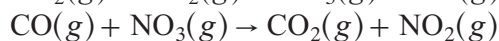
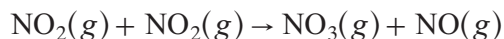


Questions 20–22 should be answered with reference to the reaction



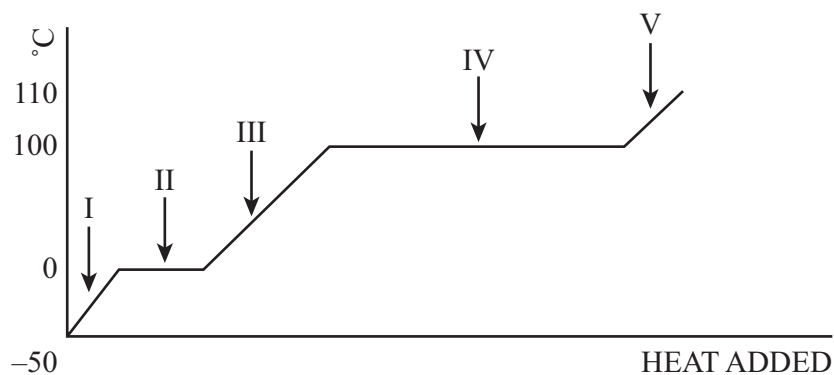
which is believed to occur by the mechanism below



- (A) NO(g)
- (B) NO<sub>2</sub>(g)
- (C) NO<sub>3</sub>(g)
- (D) CO(g)

20. Which substance is a reaction intermediate?
21. This substance appears in the rate equation only if the second step is rate-determining.
22. This substance appears in the rate equation regardless of which mechanism step is rate-determining.

Questions 23–25 refer to the heating curve for water.

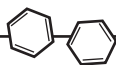


23. During which segment is the increase in potential energy the greatest?

- (A) II
- (B) III
- (C) IV
- (D) V

24. During which segment is the increase in kinetic energy the greatest?

- (A) II
- (B) III
- (C) IV
- (D) V



25. Which section represents the greatest increase in entropy ( $\Delta S$ )?

- (A) II
- (B) III
- (C) IV
- (D) V

Questions 26–27 refer to the dissolving of potassium nitrate represented by the equation

$\text{KNO}_3(s) \rightarrow \text{K}^+(aq) + \text{NO}_3^-(aq)$ . This reaction was carried out in a Styrofoam insulated calorimeter and the following data were recorded:

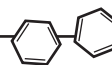
Mass of solid $\text{KNO}_3$ dissolved	10.1 g
Mass of aqueous solution (sp. heat = $4.18 \text{ J/g}^\circ\text{C}$ )	100 g
T initial	$30.0^\circ\text{C}$
T final	$21.6^\circ\text{C}$
Molar Mass of $\text{KNO}_3$	101 g

26. Which of the following equations correctly shows the heat of solution (kJ/mole) for the dissolving of  $\text{KNO}_3$ ?

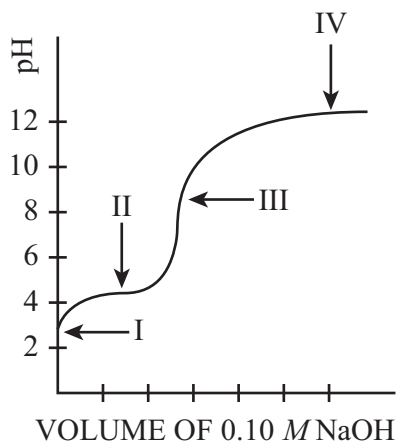
- (A)  $\text{KNO}_3(s) + 35.1 \text{ kJ} \rightarrow \text{K}^+(aq) + \text{NO}_3^-(aq)$
- (B)  $\text{KNO}_3(s) + 3.51 \text{ kJ} \rightarrow \text{K}^+(aq) + \text{NO}_3^-(aq)$
- (C)  $\text{KNO}_3(s) \rightarrow \text{K}^+(aq) + \text{NO}_3^-(aq) + 8.4 \text{ kJ}$
- (D)  $\text{KNO}_3(s) \rightarrow \text{K}^+(aq) + \text{NO}_3^-(aq) + 3510 \text{ kJ}$

27. If the mass of  $\text{KNO}_3$  solid dissolved were doubled while all other experimental conditions were kept the same, what change would occur in  $\Delta T$ , J per reaction, J/g of  $\text{KNO}_3$  and kJ/mole  $\text{KNO}_3$ ?

- |     | $\Delta T$ of solution | J per reaction | J/gram $\text{KNO}_3$ | kJ/mole $\text{KNO}_3$ |
|-----|------------------------|----------------|-----------------------|------------------------|
| (A) | Larger                 | Larger         | Larger                | Larger                 |
| (B) | Larger                 | Larger         | Larger                | No change              |
| (C) | Larger                 | Larger         | No change             | No change              |
| (D) | Larger                 | No change      | No change             | No change              |



Questions 28–30 should be answered with reference to the curve below for the titration of the acid HA with NaOH



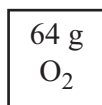
- (A) I
- (B) II
- (C) III
- (D) IV

28. At which point are the concentrations of HA and  $A^-$  equal to one another?

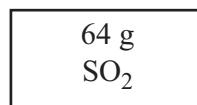
29. Which point has the highest electrical conductivity?

30. Which point is the equivalence point?

31. Consider two gases,  $O_2$  and  $SO_2$ , in fixed containers pictured below:



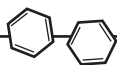
1.0 Liters  
273 K



2.0 Liters  
273 K

All of the following statements comparing the two gases are correct EXCEPT

- (A) Their average kinetic energies are equal.
- (B) The density of  $O_2$  is twice the density of  $SO_2$ .
- (C) The pressure of  $O_2$  is twice the pressure of  $SO_2$ .
- (D) The average molecular velocity of  $O_2$  is greater than  $SO_2$ .



47. For which of the following compounds does hydrogen bonding affect its physical properties?

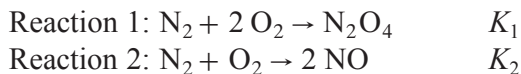
- (A) Ethane,  $\text{CH}_3\text{—CH}_3$
- (B) Ethanol,  $\text{CH}_3\text{—CH}_2\text{—OH}$
- (C) Dimethyl ether,  $\text{CH}_3\text{—O—CH}_3$
- (D) Methyl fluoride,  $\text{CH}_3\text{—F}$

48. According to the Standard Reduction Potentials in the Table below, which metal listed would be the most effective sacrificial anode in the presence of the other metals?

Selected Standard Reduction Potentials at 25 °C	$E^\circ$ , volts
$\text{Cl}_2(aq) + 2 e^- \rightarrow 2 \text{Cl}^-(aq)$	+ 1.36
$\text{I}_2(s) + 2 e^- \rightarrow 2 \text{I}^-(aq)$	+ 0.54
$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$	+ 0.80
$\text{Cu}^{2+}(aq) + 2 e^- \rightarrow \text{Cu}(s)$	+ 0.34
$\text{Pb}^{2+}(aq) + 2 e^- \rightarrow \text{Pb}(s)$	-0.12
$\text{Mg}^{2+}(aq) + 2 e^- \rightarrow \text{Mg}(s)$	-2.36

- (A) Cu
- (B) Ag
- (C) Pb
- (D) Mg

49. For the reaction,  $2 \text{NO} + \text{O}_2 \rightarrow \text{N}_2\text{O}_4$ , what is its  $K$  value in terms of the  $K$  values for Reaction 1 and Reaction 2 below?



- (A)  $K = K_1 - K_2$
- (B)  $K = K_1 \times K_2$
- (C)  $K = K_1/K_2$
- (D)  $K = K_2/K_1$

50. Which of the following solids conducts electricity when melted?

- (A) Sand,  $\text{SiO}_2$
- (B) Ice,  $\text{H}_2\text{O}$
- (C) Wax,  $\text{C}_{25}\text{H}_{52}$
- (D) Salt,  $\text{NaCl}$

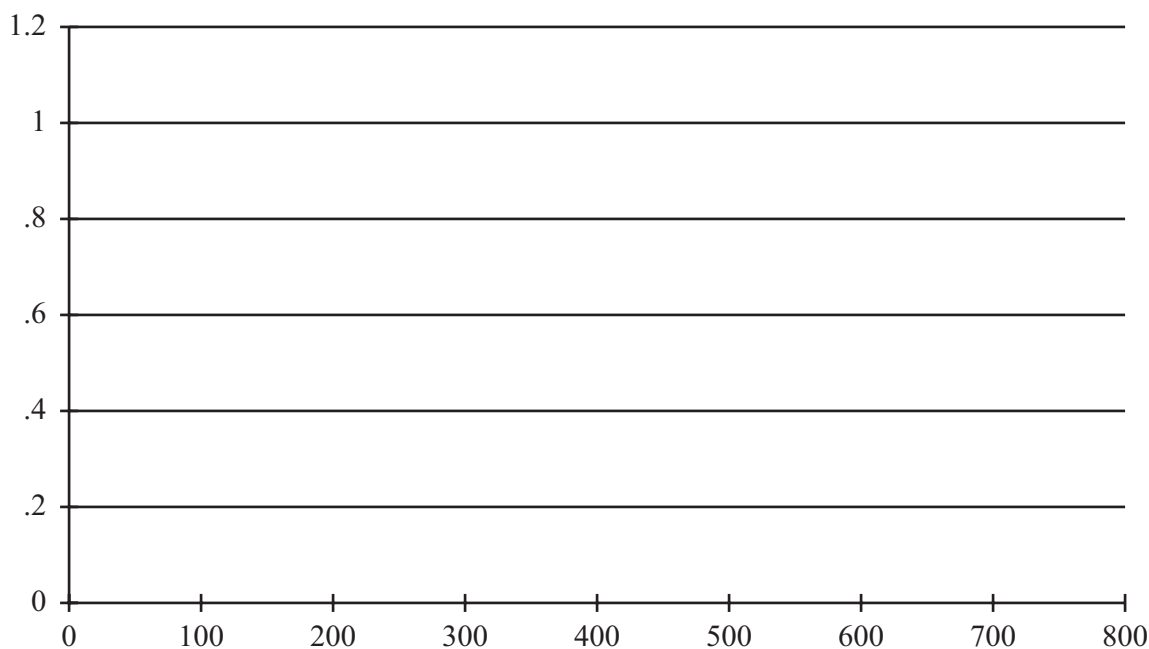
# CONSTRUCTED-RESPONSE QUESTIONS

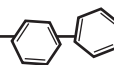
## Question 1

- The visible portion of the electromagnetic spectrum has wavelengths measuring 400 to 750 nm.
  - What is the frequency of red light with wavelength 651 nm?
  - What is the energy (J) for one photon of this red light?
- Data to establish an absorption spectrum for the permanganate anion were taken across the visible spectrum:

Absorbance	0	0.40	0.91	1.02	0.42	0.37	0
$\lambda$ (nm)	400	450	500	550	600	650	700

- On the axes below, sketch the absorbance curve for the permanganate anion. Label each axis.
- Although maximum absorbance occurs in the yellow (550-580 nm) part of the spectrum, permanganate anion has a characteristic purple color. Explain.





3. At 25°C, gaseous dinitrogen pentoxide decomposes into the gaseous products nitrogen dioxide and oxygen. The product nitrogen dioxide has a reddish-brown color while both dinitrogen pentoxide and oxygen gases are colorless. The progress of the reaction can be followed by measuring the absorbance as the reddish-brown product accumulates.
- Write a balanced net ionic equation with lowest whole number coefficients to describe the decomposition.
  - The reaction is found to be first-order. Which function of  $[\text{N}_2\text{O}_5]$  would give a straight line if plotted against time  $t$ ? What is the significance of the slope of that line?
  - At 25°C, the rate constant  $k$  for the reaction is  $4.12 \times 10^{-3} \text{ min}^{-1}$  but at 67°C, its value is  $0.35 \text{ min}^{-1}$ . Describe how you could use these values to determine the activation energy  $E_a$  for the reaction.