Chemistry 12

EQUILIBRIUM, ENTHALPY & ENTROPY

KEY

1. What do people mean when they say that a reaction is ***reversible?***
   can go forward or in reverse
2. Give *four* things which are true about a system ***at equilibrium***:
   1. system is closed
   2. rate of forward rxn = rate of reverse rxn
   3. equilib. reached starting w reactants or prod.
   4. no change in macroscopic properties
   5. T is constant
3. What is meant by ***macroscopic properties***?
   properties that are measurable / observable
4. Give some examples of macroscopic properties:
   colour, pressure, density, temp.
5. What happens to macroscopic properties ***at equilibrium***?
   nothing - remain constant
6. How do the rates of the forward and reverse reaction compare at equilibrium?
   they are equal
7. Do the forward and reverse reactions stop at equilibrium? no
8. What can be said about the concentrations of all reactants and products ***at equilibrium***?
   they remain constant
9. Why is chemical equilibrium called ***dynamic equilibrium***? "changing"
   reactants changing to produce products;
   products changing to produce reactants

10. Given the reaction: $A + B \rightleftarrows C + D$

When 1.0 mole of A is combined with 1.0 mole of B, an equilibrium is established in which [A] = 0.2 M, [B] = 0.2 M , [C] = 0.8 M and [D] = 0.8 M
If, at the same temperature, 1.0 mole of C and 1.0 mole of D is combined. When equilibrium is established, determine what the following concentrations will be:

[A] = 0.2 M, [B] = 0.2 M , [C] = 0.8 M and [D] = 0.8 M

11. Given sufficient activation energy, a system ***not at equilibrium*** will eventually move toward equilibrium.

12. Systems will tend toward a position of minimum ***enthalpy.***

13. Systems will tend toward a position of maximum ***entropy.***

14. Tell whether each of the following is ***endothermic*** or ***exothermic*** and state which has ***minimum enthalpy,*** the *reactants* or the *products*:

a. $Cl_{2(g)} + PCl_{3(g)} \rightleftarrows PCl_{5(g)}$ $\Delta H = -92.5$ kJ

exo thermic and the products have *minimum enthalpy.*

b. $2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$ $\Delta H = 92.4$ kJ

endo thermic and the reactants have *minimum enthalpy.*

c. $CH_{4(g)} + H_2O_{(g)} + 49.3\text{ kJ} \rightleftarrows CO_{(g)} + 3H_{2(g)}$

endo thermic and the reactants have *minimum enthalpy.*

15. If the reaction: $Cl_{2(aq)} \rightleftharpoons Cl_{2(g)}$ $\Delta H = +25$ kJ endo

was proceeding to the *right*, the enthalpy would be increasing ing. Is this a *favourable* change? no.

16. If the reaction: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + 92.4$ kJ

was proceeding to the *right*, the enthalpy would be decreasing ing. Is this a *favourable* change? yes.

17. For each of the following, decide whether the ***reactants*** or the ***products*** have ***greater entropy***:

a) $I_{2(s)} \rightleftarrows I_{2(g)}$ The product have greater entropy.

b) $4PH_{3(g)} \rightleftarrows P_{4(g)} + 6H_{2(g)}$

The products (7 mol gas v. 4 mol gas) have greater entropy.

c) $NH_{3(g)} \rightleftarrows NH_{3(aq)}$

The reactant have greater entropy.

18. When the two tendencies ***oppose each other*** (one favours reactants, the other favours products), the reaction will reach state of equilibrium

Processes in which ***both*** the tendency toward ***minimum enthalpy*** and toward ***maximum entropy*** favour the ***products***, will go to completion

Processes in which ***both*** the tendency toward ***minimum enthalpy*** and toward ***maximum entropy*** favour the ***reactants***, will not occur

19. For each of the following reactions decide which has ***minimum enthalpy*** (reactants or products), which has ***maximum entropy*** (reactants or products), and if the reactants are mixed, what will happen? (go to completion/ reach a state of equilibrium/not occur at all).

a) $4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + 114.4\ kJ$

The products have minimum enthalpy.

The reactants have maximum entropy.

If HCl + O_2 are put together, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)
reach a state of equilib

b) $CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$; $\Delta H = 42.6\ kJ$

The reactants have minimum enthalpy.

How does the entropy of the reactants and products compare? same
If $CO_{2(g)} + H_{2(g)}$ were put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)
not occur (or v. little)

c) $4PH_{3(g)} \rightleftarrows P_{4(s)} + 6H_{2(g)} + 37\ kJ$

The products has/have minimum enthalpy.

The products has/have maximum entropy.

If $PH_{3(g)}$ was put in a flask what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

go to completion

20. Do systems always reach ***minimum enthalpy*** at equilibrium? no

Explain. tendency to max entropy may oppose it

21. Do systems always reach ***maximum entropy*** at equilibrium? no

Explain. tendency to min enthalpy may oppose it

22. A "heat term" in a chemical equation shows what is happening to the enthalpy

and really has nothing to do with the entropy
(Answers are either entropy or enthalpy)

23. As a reaction approaches equilibrium, the rate of the forward reaction decreases,

while the rate of the reverse reaction increases.

Once equilibrium is reached, the rates become equal

24. Consider the reaction: $BaCO_{3(s)}$ + heat $\rightleftarrows BaO_{(s)} + CO_{2(g)}$

Which one of the following observations will indicate that the reaction has most likely achieved ***equilibrium***?

a) The mass of the system becomes constant - mass will not Δ
b) The concentration of $BaO_{(s)}$ becomes constant - solids don't have [ ]
c) All the $BaCO_3$ is consumed. - no... at equil.
d) The gas pressure of the system becomes constant

Your answer is d. Explain why. pressure - macroscopic property → constant @ equilibrium

25. Consider the following reaction: $Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$

A solution of $Fe(NO_3)_3$ is added to a solution of KSCN. As equilibrium is being established,
the $[Fe^{3+}]$ is decreasing and the $[FeSCN^{2+}]$ increasing

26. A system has reached equilibrium when:

a) maximum entropy has been achieved
b) minimum enthalpy has been achieved
c) the rate of the forward reaction and reverse reaction is zero
d) the concentrations of reactants and products have stopped changing

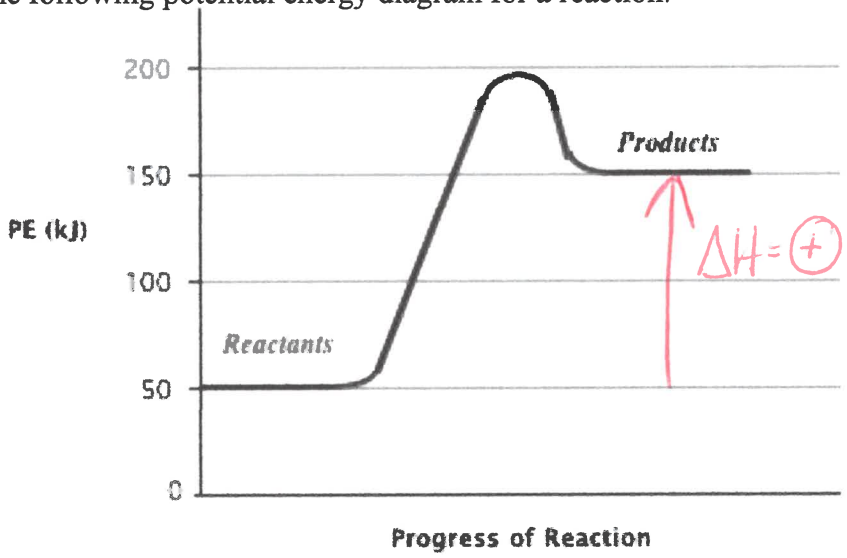
Your answer is d. Explain why concentration - macroscopic property - does not Δ @ equilib.

27. Equilibrium is achieved when reactant and product concentrations are (equal/constant/zero)
constant

28. In a particular chemical reaction, ΔH = +100 kJ. When equilibrium has been established, it is found that a significant amount of product has formed, even though there is still some reactants left.

What has happened to ***entropy*** as this reaction was taking place? increased
Explain how you arrived at your answer exothermic favours reactants so entropy must favour products for rxn to be @ equilib

29. Given the following potential energy diagram for a reaction:



Explain in terms of enthalpy and entropy, how you could end up with a fairly high ratio of products to reactants.

endothermic → favours reactants
entropy - must favour products
... even though products have more E, rxn goes because of ↑ entropy