DYNAMIC EQUILIBRIUM STUDY GUIDE

multiple choice

Multiple Choice Section: This study guide is a compilation of questions from provincial exams since April 1994. I urge you to become intimately familiar with question types. You will notice that questions from one year to another are very similar in their composition. Identification of question types will allow you to be more efficient in answering these questions on the provincial examination. My recommendations for using this study guide are as follows :

1. **DO ALL THE QUESTIONS** in this booklet. These are actual Provincial Exam questions! Your own provincial exam and unit test will include questions similar to the ones in this booklet!
2. **RESIST THE URGE TO LOOK AT THE ANSWER KEY** until you have given all the questions in the section your best effort. Don't do one question, then look at the key, then do another and look at the key, and so on. Each time you look at one answer in the study guide, your eye will notice other answers around them, and this will reduce the effectiveness of those questions in helping you to learn.
3. **LEARN FROM YOUR MISTAKES**! If you get a question wrong, **figure out why**! If you are having difficulty, **talk to your study partner**, or maybe **phone someone in your Peer Tutoring group**. Get together with group members or other students from class and work on these questions together. Explain how you got your answers to tough questions to others. In explaining yourself to someone else, you will learn the material better yourself (try it!) Ask your teacher to explain the questions to you during tutorial or after school. **Your goal should be to get 100% on any Chemistry 12 multiple choice test**- learning from your mistakes in this booklet will really help you in your efforts to meet this goal!
4. **This is REALLY CRUCIAL**: **DO NOT mark the answer anywhere on the questions themselves**. For example, do not circle any of options A B C or D-instead use a different sheet of paper to place your answers on. By avoiding this urge, you can re-use this study guide effectively again, when preparing for your final exam. In the box to the left, put an asterisk or small note to yourself to indicate that you got the question wrong and need to come back to it. If you got the question correct initially, a check mark might be assurance that you understand this type of question and therefore can concentrate on other questions that present a challenge to you.
5. **Check Off the STATUS box on the PRESCRIBED LEARNING OUTCOMES sheet**. I have tried to organize the questions in the identical sequence to which they appear on your **Dynamic Equilibrium** Prescribed Learning Outcome sheet. By doing this, you can be confident that you know everything you need to know for both the UNIT EXAM and PROVINCIAL EXAM !

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PART ONE- MULTIPLE CHOICE

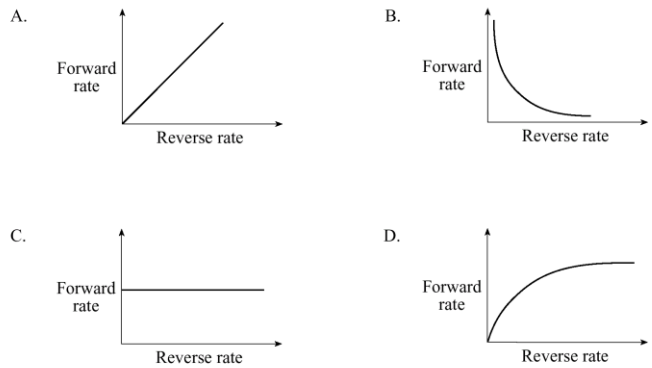
CHEM.....IS....TRY

INTRODUCTION TO EQUILIBRIUM

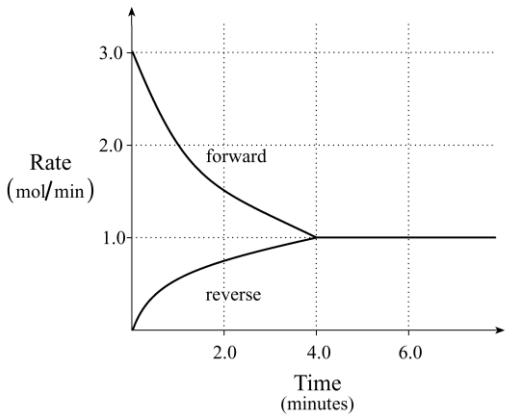
1 D1 **A saturated NaCl $_{(aq)}$ solution is an example of an equilibrium system because of the reversible nature of**

A. solidifying and melting
B. crystallizing and dissolving
C. evaporating and condensing
D. crystal structure and bond energy.

2 D3 At different conditions, the relationship between the forward and reverse rates of reaction in an **equilibrium system** can be represented by:



3 D3 Consider the following graph:



When equilibrium is reached, the rate of the forward reaction is

A. 0.00 mol/min
B. 0.25mol/min
C. 1.0 mol/min
D. 3.0 mol/min

4 D3 Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$$

Nitrogen gas and oxygen gas react when placed in a closed container. As the reaction proceeds towards equilibrium, the rate of the reverse reaction

A. increases as the concentration of products decreases.
B. decreases as the concentration of products decreases.
C. increases as the concentration of products increases.
D. decreases as the concentration of products increases.

5 D3 Consider the following equilibrium:

$$H_2O_{(g)} + CO_{(g)} \rightleftarrows H_{2(g)} + CO_{2(g)}$$

At high temperature, H_2O and CO are placed in a closed container. As the system approaches equilibrium, the

A. rate of the forward and reverse reactions both increase.
B. rate of the forward and reverse reactions both decrease.
C. rate of the forward reaction decreases and the rate of the reverse reaction increases.
D. rate of the forward reaction increases and the rate of the reverse reaction decreases.

6 D3 **A 1.00 L flask contains a gaseous equilibrium system. The addition of reactants to this flask results in a :**

A. shift left and a decrease in the concentration of products.
B. shift left and an increase in the concentration of products.
C. shift right and a decrease in the concentration of products.
D. shift right and an increase in the concentration of products.

7 D3 Consider the following:

$$2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$$

A flask is initially filled with NH_3 . As the system approaches equilibrium, the rate of the <u>forward</u> reaction

A. increases as the rate of the reverse reaction decreases.
B. decreases as the rate of the reverse reaction increases.
C. increases as the rate of the reverse reaction increases.
D. decreases as the rate of the reverse reaction decreases.

8 D3 Consider the following equilibrium:

$$N_2O_{4(g)} + \text{heat} \rightleftarrows 2NO_{2(g)}$$

Initially, a 1.0 L container is filled with 2.0 mol of NO_2 . As the system approaches equilibrium, the <u>rate of reaction of NO_2</u>

A. increases and $[N_2O_4]$ increases. B. increases and $[N_2O_4]$ decreases.
C. decreases and $[N_2O_4]$ increases. D. decreases and $[N_2O_4]$ decreases.

9 D3 Consider the following equilibrium:

$$SO_2Cl_{2(g)} \rightleftarrows SO_{2(g)} + Cl_{2(g)}$$

A 1.0 L container is initially filled with 2.0 mol of SO_2Cl_2 . As the reaction proceeds towards equilibrium, the rate of the <u>forward</u> reaction

A. increases and the $[SO_2]$ increases. B. increases and the $[SO_2]$ decreases.
C. decreases and the $[SO_2]$ increases. D. decreases and the $[SO_2]$ decreases.

10 D3 Consider the following reversible reaction:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

A solution of $Fe(NO_3)_3$ is added to a solution of KSCN. Which one of the following statements describes the <u>changes</u> in forward and reverse reaction rates <u>as the reaction moves towards equilibrium</u>?

A. Forward and reverse rates increase.
B. Forward and reverse rates decrease.
C. Forward rate increases and reverse rate decreases.
D. Forward rate decreases and reverse rate increases.

11 D3 Consider the following equilibrium:

$$N_{2(g)} + 2O_{2(g)} \rightleftarrows 2NO_{2(g)}$$

Equal moles of N_2 and O_2 are added, under certain conditions, to a closed container. Which of the following describes the changes in the <u>reverse</u> reaction which occur as the system <u>proceeds toward equilibrium</u>?

	Rate of Reverse Reaction	$[NO_2]$
A.	increases	increases
B.	decreases	increases
C.	increases	decreases
D.	decreases	decreases

12 D3 Consider the following equilibrium:

$$2O_{3(g)} \rightleftarrows 3O_{2(g)} \qquad K_{eq} = 65$$

Initially 0.10 moles of O_3 and 0.10 moles of O_2 are placed in a 1.0L container. **Which of the following describes the <u>changes in concentration</u> as the reaction proceeds towards equilibrium**?

	$[O_3]$	$[O_2]$
A.	decreases	decreases
B.	decreases	increases
C.	increases	decreases
D.	increases	increases

13 D3 Consider the following equilibrium:

$$H_2O_{(g)} + CO_{(g)} \rightleftarrows H_{2(g)} + CO_{2(g)}$$

A closed container is initially filled with H_2O and CO. As the reaction <u>proceeds towards</u> equilibrium the:

A. [CO] and $[CO_2]$ both increase. B. [CO] and $[CO_2]$ both decrease.
C. [CO] increases and $[CO_2]$ decreases. D. [CO] decreases and $[CO_2]$ increases.

14 D4 **Which of the following describes <u>all chemical equilibrium systems</u>**?

A. The mass of the reactants equals the mass of the products.
B. The species are present in the same ratio as in the balanced equation.
C. The rate of the forward reaction equals the rate of the reverse reaction.
D. The concentration of the reactants equals the concentration of the products.

15 D4 **Which of the following apply to <u>all equilibrium systems</u>?**

I	Forward and reverse rates are equal
II	Macroscopic properties are constant
III	Mass of reactants equals mass of products

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

16 D4 Consider the following:

I	forward and reverse rates are equal
II	macroscopic properties are constant
III	can be achieved from either direction
IV	concentrations of reactants and products are equal

Which of the above are true for <u>all equilibrium systems</u>?

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

17 D4 **In <u>all</u> systems at equilibrium, the**
A. concentration of reactants is less than the concentration of products.
B. concentration of reactants and the concentration of products are equal.
C. concentration of reactants is greater than the concentration of products.
D. concentration of reactants and the concentration of products are constant.

18 D4 Consider the following equilibrium:

$$2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)}$$

At equilibrium, the rate of decomposition of SO_3
A. equals the rate of formation of O_2 B. equals the rate of formation of SO_3
C. is less than the rate of formation of O_2 D. is less than the rate of formation of SO_3

19 D4 **Which of the following statements are true for <u>all</u> equilibrium systems**?
I. Macroscopic properties are constant.
II. Mass of the reactants equals mass of the products.
III. An equilibrium can be achieved from either products or reactants.

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

20 D4 **Which of the following is true for <u>all</u> equilibrium systems**?
A. The mass of reactants is equal to the mass of products.
B. Addition of a catalyst changes the equilibrium concentrations.
C. The concentration of reactants is equal to the concentration of products.
D. The rate of the forward reaction is equal to the rate of the reverse reaction.

21 D4 **Which of the following is characteristic of <u>all</u> systems at equilibrium**?
A. Activation energy is not required.
B. Changes do not occur at the microscopic level.
C. Two opposing reactions occur at the same rate.
D. Temperature and pressure affect the equilibrium position equally.

22 D4 Consider the following:

I	constant temperature
II	equal concentrations of reactants and products
III	equal rates of forward and reverse reactions

A system at equilibrium <u>must</u> have
A. I and II only B. I and III only C. II and III only D. I, II and III.

23 D4 **Macroscopic properties become <u>constant</u> in an equilibrium system <u>when</u>**
A. all reactions have stopped. B. the reactants are completely used up.
C. maximum enthalpy has been reached. D. forward and reverse reaction rates are equal.

24 D4 **Which of the following does <u>not</u> apply to all chemical equilibrium systems**? *AUG 2000*
A. They are closed
B. The macroscopic properties are constant.
C. Forward and reverse reaction rates are equal.
D. There are equal concentrations of reactants and products.

25 D4 **Which of the following applies to a <u>chemical equilibrium</u>?**

I.	Forward and reverse reaction rates are equal
II.	Equilibrium can be achieved from either direction
III.	Macroscopic properties are constant

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

26 D5 **Chemical equilibrium is said to be <u>dynamic</u> because**
A. the reaction proceeds quickly. B. the mass of the reactants is decreasing.
C. the macroscopic properties are constant. D. both forward and reverse reactions are occurring.

27 D5 **Equilibrium is a <u>dynamic</u> process because the**
A. macroscopic properties are not changing.
B. mass of reactants equals the mass of products.
C. forward and reverse reactions continue to occur.
D. concentrations of the reactants and products are constant.

28 D5 **Equilibrium is said to be <u>dynamic</u> because the**
A. forward and reverse reactions stop B. reverse reaction goes to completion.
C. forward reaction goes to completion D. forward and reverse reactions continue.

29 D5 **A system at equilibrium is said to be <u>dynamic</u> because at equilibrium the**
A. temperature does not change.
B. macroscopic properties are constant.
C. forward and reverse reactions continue to occur.
D. concentrations of reactants and products are constant.

30 D5 **A chemical equilibrium is described as <u>dynamic</u> because** :
A. maximum randomness has been achieved.
B. the pressure and temperature do not change.
C. both reactants and products continue to form.
D. the concentrations of chemical species remain constant.

31 D7 Consider the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)} + \text{energy}$$

Which of the following describes the changes in <u>enthalpy</u> and <u>entropy</u> as the <u>reaction proceeds</u>?

	ENTHALPY	ENTROPY
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

32 D7 In which reaction is entropy decreasing?

A. $H_2O_{(\ell)} \rightarrow H_2O_{(g)}$

B. $N_2O_{4(g)} \rightarrow 2NO_{2(g)}$

C. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

D. $Fe^{3+}{}_{(aq)} + SCN^{-}{}_{(aq)} \rightarrow FeSCN^{2+}{}_{(aq)}$

33 D7 Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + 92\ \text{kJ}$$

The <u>forward</u> reaction is
A. exothermic and entropy is increasing. B. exothermic and entropy is decreasing.
C. endothermic and entropy is increasing. D. endothermic and entropy is decreasing.

34 D7 **In which reaction is the enthalpy of the reactants <u>greater than</u> the enthalpy of the products**?

A. $H_2O_{(s)} \rightarrow H_2O_{(\ell)}$

B. $H_2O_{(s)} \rightarrow H_2O_{(g)}$

C. $H_2O_{(\ell)} \rightarrow H_2O_{(s)}$

D. $H_2O_{(\ell)} \rightarrow H_2O_{(g)}$

35 D7 Consider the following reaction:

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(\ell)} \qquad \Delta H = -27.7\ kJ$$

In this reaction,
A. minimum enthalpy and maximum entropy both favour products.
B. minimum enthalpy and maximum entropy both favour reactants.
C. minimum enthalpy favours products and maximum entropy favours reactants.
D. minimum enthalpy favours reactants and maximum entropy favours products.

36 D7 Consider the following possible reaction:

$$N_2O_{(g)} + NO_{2(g)} \rightarrow 3NO_{(g)} \qquad \Delta H = +156\ kJ$$

Which of the following statements is <u>correct</u>?
A. Minimum enthalpy and maximum entropy both favour the products.
B. Minimum enthalpy and maximum entropy both favour the reactants.
C. Minimum enthalpy favours the reactants and maximum entropy favours the products.
D. Minimum enthalpy favours the products and maximum entropy favours the reactants.

37 D7 Consider the following equilibrium:

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} + 59\ kJ$$

For the above reaction,
A. both minimum enthalpy and maximum entropy favour products.
B. both minimum enthalpy and maximum entropy favour reactants.
C. minimum enthalpy favours reactants and maximum entropy favours products.
D. minimum enthalpy favours products and maximum entropy favours reactants.

38 D7 In which of the following does the entropy decrease?

A. $NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

B. $4NO_{(g)} + 6H_2O_{(g)} \rightarrow 4NH_{3(g)} + 5O_{2(g)}$

C. $2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$

D. $CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(\ell)}$

39 D7 **In which of the following systems will the factors of entropy and enthalpy <u>both</u> favour the <u>reactants</u>?**

A. $3C_{(s)} + 3H_{2(g)} + \text{heat} \rightleftarrows C_3H_{6(g)}$

B. $PCl_{5(g)} + \text{heat} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$

C. $NH_4Cl_{(s)} + \text{heat} \rightleftarrows NH^+_{4(aq)} + Cl^-_{(aq)}$

D. $Cl_{2(g)} + 2HI_{(g)} \rightleftarrows I_{2(g)} + 2HCl_{(g)} + \text{heat}$

40 D7 Consider the following reaction: *AUG 2000*

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} \qquad \Delta H = -2202\ kJ$$

Which of the following applies to the <u>forward</u> reaction?

	Entropy	Enthalpy
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

41 D7 **Which of the following reactions results in an <u>entropy increase</u>**?

A. $2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$

B. $N_{2(g)} + 2H_{2(g)} \rightarrow N_2H_{4(\ell)}$

C. $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

D. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

42 D8 **In an <u>endothermic</u> equilibrium system, the**
A. minimum enthalpy and the maximum entropy both favour products.
B. minimum enthalpy and the maximum entropy both favour reactants.
C. minimum enthalpy favours products and the maximum entropy favours reactants.
D. minimum enthalpy favours reactants and the maximum entropy favours products.

43 D8 **Chemical systems tend to move toward positions of**
A. minimum enthalpy and maximum entropy.
B. maximum enthalpy and minimum entropy.
C. minimum enthalpy and minimum entropy.
D. maximum enthalpy and maximum entropy.

44 D9 Consider the enthalpy and entropy changes in the following:

$$C_2H_{2(g)} + H_{2(g)} \xrightarrow{?} C_2H_{4(g)} \qquad \Delta H = -175\ kJ$$

Which of the following statements is <u>correct</u>?
A. No reaction occurs because both the enthalpy and entropy factors favour the reactants.
B. The reaction goes to completion because both the enthalpy and entropy factors favour the product.
C. The system reaches equilibrium because the enthalpy factor favours the reactants and the entropy factor favours the product.
D. The system reaches equilibrium because the enthalpy factor favours the product and the entropy factor favours the reactants.

45 D9 **In which of the following reactions does the tendency towards minimum enthalpy and maximum entropy <u>oppose</u> each other?**

A. $3O_{2(g)} \rightarrow 2O_{3(g)}$ $\qquad \Delta H = +285\ kJ$

B. $\frac{1}{2}N_{2(g)} + O_{2(g)} \rightarrow NO_{2(g)}$ $\qquad \Delta H = +34\ kJ$

C. $2H_2O_{(g)} \rightarrow 2H_{2(g)} + O_{2(g)}$ $\qquad \Delta H = +484\ kJ$

D. $P_{4(s)} + 6H_{2(g)} \rightarrow 4PH_{3(g)}$ $\qquad \Delta H = +37\ kJ$

46 D9 **In which of the following systems would the tendencies toward minimum enthalpy and maximum entropy be in <u>opposition</u> to each other?**

A. $Br_{2(l)} + \text{heat} \rightarrow Br_{2(g)}$

B. $NaOH_{(s)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)} + \text{heat}$

C. $2C_{(g)} + 2H_{2(g)} \rightarrow C_2H_{4(g)}$ ΔH is positive

D. $K_{(s)} + H_2O_{(1)} \rightarrow K^{+}_{(aq)} + OH^{-}_{(aq)} + \frac{1}{2}H_{2(g)}$ ΔH is negative

47 D9 **In which of the following do both minimum enthalpy and maximum entropy factors <u>favor the reactants</u>?**

A. $Cl_{2(g)} \rightleftarrows Cl_{2(aq)}$ $\Delta H = -25\,kJ$

B. $C_{(s)} + H_2O_{(\ell)} \rightleftarrows CO_{(g)} + H_{2(g)}$ $\Delta H = +131\,kJ$

C. $2CO_{2(g)} + 3H_2O_{(g)} \rightleftarrows C_2H_5OH_{(\ell)} + 3O_{2(g)}$ $\Delta H = +1239\,kJ$

D. $Na_2CO_{3(s)} + HCl_{(aq)} \rightleftarrows 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(\ell)}$ $\Delta H = -28\,kJ$

48 D9 **In which of the following will the driving forces of minimum enthalpy and maximum entropy <u>oppose</u> one another?**

A. $2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$ $\Delta H = -221\,kJ$

B. $2N_{2(g)} + O_{2(g)} \rightarrow 2N_2O_{(g)}$ $\Delta H = +164\,kJ$

C. $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$ $\Delta H = -566\,kJ$

D. $4CO_{2(g)} + 6H_2O_{(g)} \rightarrow 2C_2H_{6(g)} + 7O_{2(g)}$ $\Delta H = +3122\,kJ$

LE CHATELIER'S PRINCIPLE

49 E2 Consider the following equilibrium:

$$4NH_{3(g)} + 5O_{2(g)} \rightleftarrows 4NO_{(g)} + 6H_2O_{(g)} + \text{energy}$$

Which of the following will cause the equilibrium to <u>shift to the left</u>?

A. adding $H_2O_{(g)}$ B. removing some $NO_{(g)}$ C. increasing the volume D. decreasing the temperature

50 E2 Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} + \text{energy}$$

When the <u>volume</u> of the container is <u>increased</u>, the equilibrium shifts to the

A. left and K_{eq} decreases. B. right and K_{eq} increases.
C. left and K_{eq} remains constant. D. right and K_{eq} remains constant.

51 E2 Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} + \text{energy}$$

Which of the following will cause this equilibrium to <u>shift to the left</u>?

A. adding a catalyst B. adding some SO_2 C. increasing the volume D. decreasing the temperature

52 E2 Consider the following equilibrium:

$$2NO_{(g)} + Br_{2(g)} + \text{energy} \rightleftarrows 2NOBr_{(g)}$$

The equilibrium <u>will shift to the left</u> as a result of:

A. adding a catalyst. B. removing NOBr. C. increasing the volume. D. increasing the temperature.

53 E2 Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} + \text{energy} \rightleftarrows 2NO_{(g)}$$

When the temperature is increased, the <u>equilibrium shifts to the</u>

A. left and K_{eq} increases. B. left and K_{eq} decreases.
C. right and K_{eq} increases. D. right and K_{eq} decreases.

54 E2 Consider the following equilibrium:

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} + \text{energy}$$

The equilibrium will <u>shift to the left</u> as a result of

A. adding a catalyst. B. increasing the volume.
C. removing some N_2O_4 . D. decreasing the temperature.

55 E2 Consider the following equilibrium:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)}$$

<u>The addition of H_2</u> will cause the equilibrium to shift to the

A. left and $[CH_4]$ will increase. B. left and $[CH_4]$ will decrease.
C. right and $[CH_4]$ will increase. D. right and $[CH_4]$ will decrease.

56 E2 Consider the following equilibrium:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

The <u>equilibrium concentration of PCl_5</u> will <u>increase</u> when

A. PCl_3 is added B. Cl_2 is removed
C. a catalyst is added D. the volume of the container is increased.

57 E2 Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

If the volume of the container is decreased, the

A. K_{eq} decreases B. $[N_2O_4]$ increases C. equilibrium does not shift D. equilibrium shifts to the right.

58 E2 Consider the following equilibrium:

$$NH_{3(g)} + HCl_{(g)} \rightleftarrows NH_4Cl_{(s)} + \text{energy}$$

Which of the following will result in a <u>decrease in the mass</u> of <u>NH_4Cl</u> ?

A. adding NH_3 B. removing HCl C. decreasing the volume D. decreasing the temperature

59 E2 Consider the following equilibrium:

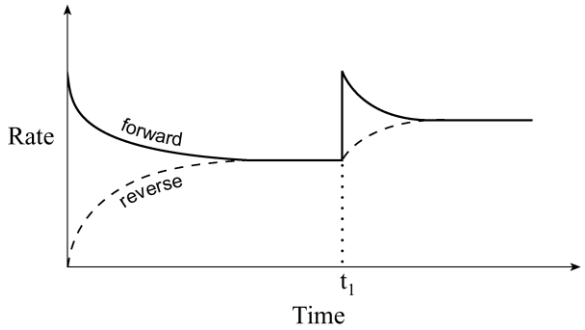
$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

The pressure on the system is increased by reducing the volume. When <u>comparing the new equilibrium with the original equilibrium,</u>

A. all concentrations remain constant.
B. the concentrations of all species have increased.
C. reactant concentrations have increased while product concentrations have decreased.
D. reactant concentrations have decreased while product concentrations have increased.

60 E2 Consider the rate diagram below for the following reaction:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)}$$



Which of the following occurs at <u>time t_1</u> ?

A. addition of H_2
B. addition of HI
C. addition of a catalyst
D. a decrease in volume

61 E2 Given the following system:

$$2CrO_4^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \rightleftarrows Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(\ell)}$$

Which of the following chemicals, when added to the above system at equilibrium, would result in a <u>decrease</u> in $[CrO_4^{2-}]$?

A. NaOH B. HNO_3 C. Na_2CrO_4 D. $Na_2Cr_2O_7$

62 E2 Consider the following equilibrium:

$$SO_{2(g)} + NO_{2(g)} \rightleftarrows SO_{3(g)} + NO_{(g)} + \text{energy}$$

The equilibrium does <u>not</u> shift with a change in the

A. volume. B. temperature. C. concentration of products. D. concentration of reactants.

63 E2 Consider the following equilibrium:

$$SO_2Cl_{2(g)} + \text{energy} \rightleftarrows SO_{2(g)} + Cl_{2(g)}$$

When the <u>temperature is decreased</u>, the equilibrium shifts

A. left and $[SO_2Cl_2]$ increases. B. left and $[SO_2Cl_2]$ decreases.
C. right and $[SO_2Cl_2]$ increases. D. right and $[SO_2Cl_2]$ decreases.

64 E2 Consider the following equilibrium:

$$N_2O_{4(g)} + 58\text{ kJ} \rightleftarrows 2NO_{2(g)}$$

The <u>equilibrium shifts right when</u>

A. NO_2 is added B. N_2O_4 is removed
C. the temperature is decreased D. the volume of the system is increased.

65 E2 Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(g)} + \text{heat} \rightleftarrows CO_{(g)} + 3H_{2(g)}$$

In which of the following will <u>both stresses</u> shift the <u>equilibrium right</u>?
A. a decrease in temperature and a decrease in volume
B. an increase in temperature and a decrease in volume
C. a decrease in temperature and an increase in volume
D. an increase in temperature and an increase in volume

66 E2 Consider the following equilibrium:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)} \qquad \Delta H = -68 \text{ kJ}$$

Which of the following would <u>cause</u> the <u>equilibrium to shift right</u>?
A. Increasing the volume. B. Decreasing the volume.
C. Increasing the temperature. D. Decreasing the temperature.

67 E2 Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$

Which of the following will <u>shift</u> the <u>equilibrium to the right</u>?
I. adding more O 2
II. adding more SO 3
III. adding a catalyst

A. I only B. III only C. I and II only D. II and III only

68 E2 Consider the following equilibrium:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)}$$

At constant temperature and volume, more I_2 is added to the above equilibrium. A <u>new</u> state of equilibrium <u>results from</u> a shift to the
A. left with a net decrease in $[H_2]$. B. left with a net increase in $[H_2]$.
C. right with a net increase in $[H_2]$. D. right with a net decrease in $[H_2]$.

69 E2 **When the temperature of an equilibrium system is increased, the equilibrium <u>always</u> shifts to <u>favour</u> the**
A. exothermic reaction. B. endothermic reaction. C. formation of products. D. formation of reactants.

70 E2 Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + 92 \text{ kJ}$$

In which of the following will both changes <u>shift the equilibrium right</u>?
A. An increase in volume and a decrease in temperature.
B. An increase in volume and an increase in temperature.
C. A decrease in volume and a decrease in temperature.
D. A decrease in volume and an increase in temperature.

71 E2 Consider the following equilibrium:

$$H_{2(g)} + CO_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)} \qquad \Delta H = +41 \text{ kJ}$$

The temperature of the above equilibrium system is <u>increased</u> while kept at a constant volume. A new state of equilibrium is established in which there is
A. an increase in [CO] and a decrease in K_{eq} B. an increase in [CO] and an increase in K_{eq}
C. an increase in $[CO_2]$ and a decrease in K_{eq} D. an increase in $[CO_2]$ and an increase in K_{eq}

72 E2 Consider the following equilibrium:

$$2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)}$$

The <u>volume</u> of the system is <u>decreased</u> at a <u>constant temperature</u>. A new state of equilibrium is established by a shift of the <u>original</u> equilibrium to the

A. left and $[SO_3]$ increases. B. right and $[SO_3]$ decreases.
C. left and $[SO_3]$ remains unchanged. D. right and $[SO_3]$ remains unchanged.

73 E2 Consider the following equilibrium system:

$$NH_{3(aq)} + H_2O_{(l)} \rightleftarrows NH_{4(aq)}^{+} + OH_{(aq)}^{-}$$

Which of the following <u>when added</u> to the above equilibrium system, would cause an <u>increase</u> in $[OH^-]$?

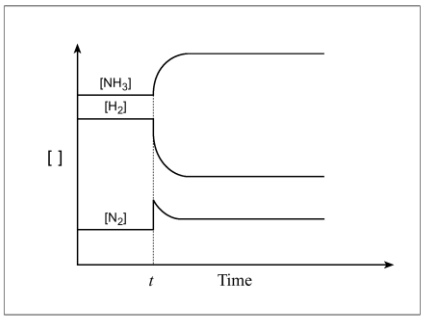
A. NH_3 B. H_2O C. NH_4^+ D. HCl

74 E2 Consider the following graph which relates to this equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} \qquad \Delta H = -92 \text{ kJ}$$

Which of the following <u>caused</u> the changes in the concentrations at time *t* ?

A. addition of N_2
B. removal of H_2
C. decrease in temperature
D. decrease in reaction volume



75 E2 Consider the following equilibrium:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)} + 74 \text{ kJ}$$

When a small amount of <u>solid</u> C is added to the system,

A. $[H_2]$ decreases B. $[CH_4]$ increases.
C. the temperature increases D. all concentrations remain constant.

76 E2 Consider the following equilibrium system:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$$

Which of the following when added to the system above would result in a net decrease in $[H_2O]$

A. CO_2 B. H_2 C. CO D. H_2O

77 E2 **Which of the following reactions will shift left when pressure is increased <u>and</u> when temperature is decreased?**

A. $N_{2(g)} + 2O_{2(g)} + \text{heat} \rightleftarrows 2NO_{2(g)}$

B. $N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{heat}$

C. $CH_{4(g)} + H_2O_{(g)} + \text{heat} \rightleftarrows CO_{(g)} + 3H_{2(g)}$

D. $CS_{2(g)} + 4H_{2(g)} \rightleftarrows CH_{4(g)} + 2H_2S_{(g)} + \text{heat}$

78 E2 Consider the following equilibrium system:

$$FeO_{(s)} + H_{2(g)} \rightleftarrows Fe_{(s)} + H_2O_{(g)}$$

Which one of the following statements describes the effect that a <u>decrease in volume</u> would have on the position of equilibrium <u>and</u> the $[H_2]$ in the above system?

A. No shift, $[H_2]$ increases. B. Shift right, $[H_2]$ increases.
C. Shift right, $[H_2]$ decreases. D. No shift, $[H_2]$ remains constant.

79 E2 Consider the following equilibrium system:

$$CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

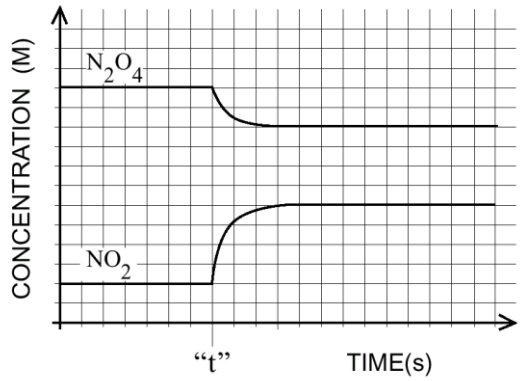
Which one of the following <u>changes</u> would cause the above system to <u>shift left</u>?
A. Add more CaO . B. Remove $CaCO_3$ C. Decrease volume D. Increase surface area of CaO .

80 E2 Consider the following concentration versus time graph for the equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

At time = " t ", which one of the following <u>stresses</u> occurred?

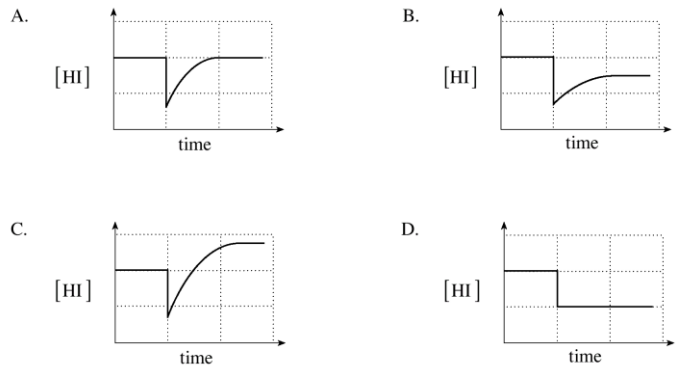
A. Catalyst was added.
B. Pressure was changed.
C. Temperature was changed.
D. Concentration of NO_2 was changed.



81 E2 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

Which graph represents what happens when some <u>HI is removed</u> and a <u>new</u> equilibrium is established?



82 E2 Consider the following equilibrium:

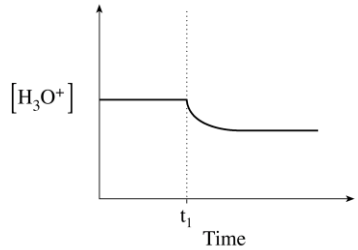
$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)} \qquad \Delta H = -41\,kJ$$

What will <u>cause a shift</u> in the equilibrium?
A. adding a catalyst B. changing volume C. adding an inert gas D. changing temperature

83 E2 Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

A stress was applied at time t_1 and the data was plotted on the following graph:



The stress that was imposed <u>at time t_1</u> is the result of:
A. the addition of HCl.
B. decreasing the temperature.
C. the addition of NaCH COO 3 .
D. increasing the volume of the container.

84 E2 Consider the following equilibrium:

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)} + \text{energy}$$

Some CO_2 is added to the equilibrium system at constant volume and a new equilibrium is established. **Compared to the original equilibrium, the <u>rates of the forward and reverse reactions for the new equilibrium have</u>:**

	FORWARD RATE	REVERSE RATE
A.	increased	increased
B.	not changed	increased
C.	decreased	increased
D.	not changed	not changed

85 E2 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

The volume of the equilibrium system is increased and a new equilibrium is established. <u>Compared to the rates in the original equilibrium,</u> which of the following describes the rates of the forward and reverse reactions in the new equilibrium?

	FORWARD RATE	REVERSE RATE
A.	decreased	decreased
B.	increased	increased
C.	decreased	increased
D.	remained constant	remained constant

86 E3 Consider the following equilibrium:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + \text{energy}$$

The temperature of the equilibrium system is <u>increased</u> and a <u>new equilibrium is established</u>. The rates of the forward and reverse reactions for the new equilibrium <u>compared to the original equilibrium</u> have

	FORWARD RATE	REVERSE RATE
A.	increased	increased
B.	decreased	not changed
C.	decreased	increased
D.	not changed	increased

87 E3 Consider the following equilibrium reaction:

$$PCl_{5(g)} + \text{energy} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

The temperature of this system is decreased. <u>What is the immediate effect on the reaction rates</u>?
A. Both forward and reverse rates increase.
B. Both forward and reverse rates decrease.
C. Forward rate decreases while reverse rate increases.
D. Forward rate increases while reverse rate decreases.

88 E3 **An equilibrium system shifts left when the temperature is increased. The <u>forward reaction</u> is**
A. exothermic and ΔH is positive. B. exothermic and ΔH is negative.
C. endothermic and ΔH is positive. D. endothermic and ΔH is negative.

89 E3 **An equilibrium system shifts <u>left</u> when the**
A. rate of the forward reaction is equal to the rate of the reverse reaction.
B. rate of the forward reaction is less than the rate of the reverse reaction.
C. rate of the forward reaction is greater than the rate of the reverse reaction.
D. rate of the forward reaction and the rate of the reverse reaction are constant.

90 E4 **Addition of a <u>catalyst</u> to an equilibrium system**
A. increases the value of K_{eq} . B. increases the yield of products.
C. has no effect on the rates of reaction. D. increases the rate of formation of both reactants and products.

91 E4 Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad \Delta H = -198 \text{ kJ}$$

There will be <u>no shift</u> in this equilibrium when

A. more O_2 is added. B. a catalyst is added.
C. the volume is increased. D. the temperature is increased.

92 E4 Consider the following equilibrium system:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad \Delta H = -197 \text{ kJ}$$

Which of the following will <u>not</u> shift the equilibrium to the right?

A. adding more O_2 B. adding a catalyst C. increasing the pressure D. lowering the temperature

93 E4 A catalyst is added to a system already at equilibrium. **How are the forward and reverse reaction rates affected by the <u>addition of the catalyst?</u>**

	FORWARD RATE	REVERSE RATE
A.	increases	increases
B.	increases	remains constant
C.	remains constant	decreases
D.	remains constant	remains constant

94 E5 Ethene, C_2H_4, can be produced in the following industrial system:

$$C_2H_{6(g)} + \text{energy} \rightleftarrows C_2H_{4(g)} + H_{2(g)}$$

The conditions that are necessary to <u>maximize the equilibrium yield of C_2H_4</u> are

A. low temperature and low pressure. B. low temperature and high pressure.
C. high temperature and low pressure. D. high temperature and high pressure.

95 E5 Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{energy}$$

Certain conditions <u>provide less than 10% yield of NH_3 at equilibrium</u>. Which of the following describes this equilibrium?

	K_{eq}	EQUILIBRIUM POSITION
A.	large	favours products
B.	small	favours products
C.	large	favours reactants
D.	small	favours reactants

96 E5 Consider the following equilibrium system:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + 92 \text{ kJ}$$

Which of the following sets of conditions will <u>favor</u> the formation of the <u>product</u>?

A. low pressure and low temperature B. low pressure and high temperature
C. high pressure and low temperature D. high pressure and high temperature

97 E5 Consider the following equilibrium:

$$Cl_2O_{7(g)} + 8H_{2(g)} \rightleftarrows 2HCl_{(g)} + 7H_2O_{(g)}$$

Which of the following would <u>increase</u> the number of <u>moles</u> of HCl ?

A. increase $[H_2O]$ B. increase $[Cl_2O_7]$
C. increase total pressure D. increase volume of the system

98 E5 Consider the following equilibrium: *AUG 2000*

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} + \text{energy}$$

The number of moles of NO_2 <u>at equilibrium</u> could be <u>increased</u> by

A. adding N_2O_4 B. adding a catalyst.
C. decreasing the temperature D. decreasing the volume by increasing the pressure.

99 E5 Ammonia, NH_3 , is produced by the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{energy}$$

Which of the following would result in the <u>highest concentration of ammonia</u> at equilibrium?

A. increasing the temperature and increasing the pressure
B. decreasing the temperature and increasing the pressure
C. increasing the temperature and decreasing the pressure
D. decreasing the temperature and decreasing the pressure

100 E5 Methanol, CH_3OH, can be produced by the following:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{energy}$$

The conditions that are necessary to <u>maximize the equilibrium yield</u> of CH_3OH are

A. low temperature and low pressure. B. high temperature and low pressure.
C. low temperature and high pressure. D. high temperature and high pressure.

THE EQUILIBRIUM CONSTANT

101 F1 **Which of the following reactions <u>most favours products</u>?**

	REACTION	K_{eq}
I	$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$	2.6×10^{2}
II	$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$	6.4×10^{5}
III	$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$	2.5×10^{15}
IV	$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)}$	1.7×10^{27}

A. I B. II C. III D. IV

102 F1 **An indication that an equilibrium system <u>favours the products</u> is a**

A. large K_{eq} . B. positive ΔH. C. one step mechanism. D. low activation energy.

103 F1 **Which of the following reactions most <u>favors the reactants</u>?**

A. $CH_{4(g)} \rightleftarrows 2H_{2(g)} + C_{(s)}$ $K_{eq} = 1.2\times10^{-9}$

B. $SbCl_{5(g)} \rightleftarrows SbCl_{3(g)} + Cl_{2(g)}$ $K_{eq} = 2.5\times10^{-2}$

C. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 4.5\times10^{-1}$

D. $C_{(s)} + CO_{2(g)} \rightleftarrows 2CO_{(g)}$ $K_{eq} = 1.4\times10^{1}$

104 F1 **Which equation has the largest value of K_{eq} ?**

A. $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$ $\Delta H = 21$ kJ

B. $C_2H_{6(g)} \rightleftarrows 2C_{(g)} + 3H_{2(g)}$ $\Delta H = 83$ kJ

C. $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightleftarrows H_2O_{(g)}$ $\Delta H = -240$ kJ

D. $Ca_{(s)} + 2H_2O_{(\ell)} \rightleftarrows Ca(OH)_{2(aq)} + H_{2(g)}$ $\Delta H = -240$ kJ

105 F1 Consider the following equilibrium:

$$2NO_{(g)} \rightleftarrows N_{2(g)} + O_{2(g)} \qquad K_{eq} = 2.1 \times 10^{30}$$

The <u>value of the equilibrium constant</u> indicates that the

A. $[NO]^2 < [N_2][O_2]$

B. $[NO]^2 > [N_2][O_2]$

C. $[NO] = [N_2][O_2]$

D. $[NO] > [N_2][O_2]$

106 F1 **Which of the following equilibrium systems most <u>favours the products</u>?**

A. $Cl_{2(g)} \rightleftarrows 2Cl_{(g)}$ $K_{eq} = 6.4 \times 10^{-39}$

B. $Cl_{2(g)} + 2NO_{(g)} \rightleftarrows 2NOCl_{(g)}$ $K_{eq} = 3.7 \times 10^{8}$

C. $Cl_{2(g)} + 2NO_{2(g)} \rightleftarrows 2NO_2Cl_{(g)}$ $K_{eq} = 1.8$

D. $2HCl_{(g)} \rightleftarrows H_{2(g)} + Cl_{2(g)}$ $K_{eq} = 2.0 \times 10^{-7}$

107 F1 Consider the following equilibrium:

$$COCl_{2(g)} \rightleftarrows CO_{(g)} + Cl_{2(g)}$$

At equilibrium in a 1.0 L container, there are 3.0 mol $COCl_2$, 0.49 mol CO and 0.49 mol Cl_2 . At constant temperature the volume of the above system is decreased to 0.50 L. When equilibrium is <u>reestablished</u> the

A. concentrations of all three gases have increased.
B. concentrations of all three gases have decreased.
C. [$COCl_2$] has increased and [CO] and [Cl_2] have decreased.
D. [$COCl_2$] has decreased and [CO] and [Cl_2] have increased.

108 F1 Consider the following equilibrium:

$$2NOCl_{(g)} \rightleftarrows 2NO_{(g)} + Cl_{2(g)}$$

In a 1.0 L container at equilibrium there are 1.0 mol NOCl, 0.70 mol NO and 0.40 mol Cl_2 . At constant temperature and volume, 0.10 mol NOCl is added. The concentrations in the <u>"new"</u> equilibrium in <u>comparison</u> to the concentrations in the <u>"old"</u> equilibrium are

	[NOCl]	[NO]	[Cl_2]
A.	new = old	new = old	new = old
B.	new > old	new > old	new > old
C.	new < old	new < old	new > old
D.	new < old	new > old	new > old

109 F1 Consider the following equilibrium:

$$2H_2O_{(g)} \rightleftarrows 2H_{2(g)} + O_{2(g)}$$

When 0.1010 mol H_2O is placed in a 1.000 L container, equilibrium is established. The equilibrium concentration of O_2 is 0.0010 mol/L. The equilibrium concentrations of H_2O and H_2 are

	$[H_2O]$	$[H_2]$
A.	0.0990	0.0020
B.	0.1000	0.0010
C.	0.1005	0.0005
D.	0.1010	0.0020

110 F1 Consider the following equilibrium:

$$COCl_{2(g)} \rightleftarrows CO_{(g)} + Cl_{2(g)} \qquad K_{eq} = 8.1 \times 10^{-4}$$

For the above system……

A. $[COCl_2] < [CO][Cl_2]$

B. $[COCl_2] = [CO][Cl_2]$

C. $[COCl_2] > [CO][Cl_2]$

D. $[COCl_2] = \frac{1}{[CO][Cl_2]}$

111 F1 Consider the following equilibrium:

$$2O_{2(g)} + N_{2(g)} \rightleftarrows N_2O_{4(g)}$$

When 2.0 mol of O_2 and 3.0 mol of N_2 were placed in a 10.0 L container at 25° C, the value of K_{eq} = 0.90. If the same number of moles of reactant were placed in a 5.0 L container at 25° C, the <u>equilibrium constant</u> would be

A. 0.011 B. 0.45 C. 0.90 D. 1.80

112 F1 Consider the following equilibrium system at 900° C:

$$H_2O_{(g)} + CO_{(g)} \rightleftarrows H_{2(g)} + CO_{2(g)}$$

Initially 5.0 moles of H_2O and 4.0 moles of CO were reacted. At equilibrium, it is found that 2.0 moles of H_2 are present. **How many moles of H_2O <u>remain</u> in the mixture**?

A. 1.0 moles B. 2.0 moles C. 3.0 moles D. 4.0 moles

113 F1 Consider the following equilibrium system:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$$

1.00 mole of CO_2 and 2.00 moles of $H_{2(g)}$ are placed into a 2.00 litre container. At equilibrium, the [CO] = 0.31 mol/L. **Based on this data, the e<u>quilibrium</u> [CO_2] is**

A. 0.19 M B. 0.31 M C. 0.38 M D. 0.69 M

114 F1 Consider the following equilibrium: *AUG 2000*

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 50.0$$

What is the <u>value</u> K_{eq} for the reaction rewritten as:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)} \qquad K_{eq} = ?$$

A. -50.0 B. 0.0200 C. 25.0 D. 50.0

115 F2 Consider the following equilibrium:

$$2Fe_{(s)} + 3H_2O_{(g)} \rightleftarrows Fe_2O_{3(s)} + 3H_{2(g)}$$

The equilibrium constant expression is……..

A. $K_{eq} = \frac{[Fe_2O_3][H_2]^3}{[Fe]^2[H_2O]^3}$

B. $K_{eq} = \frac{[Fe_2O_3][3H_2]}{[2Fe][3H_2O]}$

C. $K_{eq} = \frac{[H_2]^3}{[H_2O]^3}$

D. $K_{eq} = [H_2]^3$

116 F2 Consider the following equilibrium:

$$2H_2S_{(g)} \rightleftarrows 2H_{2(g)} + S_{2(g)}$$

At equilibrium, $[H_2S]$ =0. 50 mol/L, $[H_2]$ =0.10 mol/L and $[S_2]$ =0. 40 mol/L.

The value of K_{eq} is calculated using the ratio……..

A. $\frac{(0.10)(0.40)}{(0.50)}$

B. $\frac{(0.10)^2(0.40)}{(0.50)^2}$

C. $\frac{(0.50)}{(0.10)(0.50)}$

D. $\frac{(0.50)^2}{(0.10)^2(0.40)}$

117 F2 **For which of the following equilibria does $K_{eq} = [O_2]$?**

A. $O_{2(l)} \rightleftarrows O_{2(g)}$

B. $2O_{3(g)} \rightleftarrows 3O_{2(g)}$

C. $2H_2O_{(l)} \rightleftarrows 2H_{2(g)} + O_{2(g)}$

D. $2Hg_{(s)} + O_{2(g)} \rightleftarrows 2HgO_{(s)}$

118 F2 **Which of the following statements is <u>correct</u>?**

A. K_{eq} is the ratio of [products] to [reactants].
B. K_{eq} determines how fast a reaction is completed.
C. A large K_{eq} value indicates that reactants are favoured.
D. A small K_{eq} value indicates that products are favoured.

119 F2 Consider the following equilibrium system:

$$3O_{2(g)} \rightleftarrows 2O_{3(g)} \qquad K_{eq} = 1$$

Which equation <u>compares</u> the concentration of oxygen and ozone?

A. $[O_2] = [O_3]^{\frac{2}{3}}$

B. $[O_2] = [O_3]$

C. $[O_2] = [O_3]^{\frac{3}{2}}$

D. $[O_2]^{\frac{2}{3}} = [O_3]$

120 F2 An equal number of moles of $I_{2(g)}$ and $Br_{2(g)}$ are placed into a closed container and allowed to establish the following equilibrium:

$$I_{2(g)} + Br_{2(g)} \rightleftarrows 2IBr_{(g)} \qquad K_{eq} = 280$$

Which one of the following <u>relates</u> [IBr] to [I_2] at equilibrium?

A. $[I_2] = [IBr]$

B. $[I_2] < [IBr]$

C. $[I_2] = 2[IBr]$

D. $[I_2] = 280[IBr]$

121 F2 Consider the following reaction:

$$2Hg_{(g)} + O_{2(g)} \rightleftarrows 2HgO_{(s)}$$

The <u>equilibrium constant expression</u> for the reaction is

A. $K_{eq} = \frac{1}{[Hg]^2[O_2]}$

B. $K_{eq} = [Hg]^2[O_2]$

C. $K_{eq} = \frac{[HgO]^2}{[Hg]^2[O_2]}$

D. $K_{eq} = \frac{[2HgO]}{[2Hg][O_2]}$

122 F2 Consider the following reaction:

$$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(l)}$$

What is the <u>equilibrium constant expression</u> for the reaction?

A. $K_{eq} = [H_2]^2[O_2]$

B. $K_{eq} = \frac{[H_2]^2[O_2]}{[H_2O]^2}$

C. $K_{eq} = \frac{[H_2O]^2}{[H_2]^2[O_2]}$

D. $K_{eq} = \frac{1}{[H_2]^2[O_2]}$

123 F2 Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$

The equilibrium expression is:

A. $K_{eq} = \frac{[SO_3]}{[SO_2][O_2]}$

B. $K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$

C. $K_{eq} = \frac{[SO_2][O_2]}{[SO_3]}$

D. $K_{eq} = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$

124 F2 Consider the following equilibrium:

$$CaO_{(s)} + CO_{2(g)} \rightleftarrows CaCO_{3(s)}$$

For this reaction,

A. $K_{eq} = [CO_2]$

B. $K_{eq} = \frac{1}{[CO_2]}$

C. $K_{eq} = \frac{[CaCO_3]}{[CO_2][CaO]}$

D. $K_{eq} = \frac{[CO_2][CaO]}{[CaCO_3]}$

125 F2 Consider the following equilibrium:

$$MgO_{(s)} + H_2O_{(g)} \rightleftarrows Mg(OH)_{2(s)}$$

The <u>equilibrium constant expression</u> is…….

A. $K_{eq} = [H_2O]$

B. $K_{eq} = \frac{1}{[H_2O]}$

C. $K_{eq} = \frac{[Mg(OH)_2]}{[MgO]}$

D. $K_{eq} = \frac{[Mg(OH)_2]}{[MgO][H_2O]}$

126 F2 Consider the following reaction:

$$2B_{(s)} + 3F_{2(g)} \rightleftarrows 2BF_{3(g)}$$

The <u>equilibrium expression</u> is……

A. $K_{eq} = \frac{[2BF_3]}{[3F_2]}$

B. $K_{eq} = \frac{[F_2]^3}{[BF_3]^2}$

C. $K_{eq} = \frac{[BF_3]^2}{[F_2]^3}$

D. $K_{eq} = \frac{[BF_3]^2}{[B]^2[F_2]^3}$

127 F2 Consider the following equilibrium:

$$2N_2O_{(g)} + 3O_{2(g)} \rightleftarrows 4NO_{2(g)}$$

The equilibrium constant <u>expression</u> is…

A. $K_{eq} = \frac{[2N_2O][3O_2]}{[4NO_2]}$

B. $K_{eq} = \frac{[N_2O]^2[O_2]^3}{[NO_2]^4}$

C. $K_{eq} = \frac{[4NO_2]}{[2N_2O][3O_2]}$

D. $K_{eq} = \frac{[NO_2]^4}{[N_2O]^2[O_2]^3}$

128 F2 Given the following equilibrium system:

$$Br_{2(g)} \rightleftarrows Br_{2(l)}$$

The <u>equilibrium constant expression</u> for the above system is…..

A. $K_{eq} = \frac{[Br_{2(l)}]}{[Br_{2(g)}]}$

B. $K_{eq} = [Br_{2(g)}]$

C. $K_{eq} = \frac{1}{[Br_{2(g)}]}$

D. $K_{eq} = [Br_{2(g)}][Br_{2(g)}]$

129 F2 Consider the following equilibrium:

$$4KO_{2(s)} + 2H_2O_{(g)} \rightleftarrows 4KOH_{(s)} + 3O_{2(g)}$$

The <u>equilibrium constant expression</u> is……

A. $K_{eq} = \frac{[KOH]^4[O_2]^3}{[KO_2]^4[H_2O]^2}$

B. $K_{eq} = \frac{[O_2]^3}{[H_2O]^2}$

C. $K_{eq} = \frac{[KO_2]^4[H_2O]^2}{[KOH]^4[O_2]^3}$

D. $K_{eq} = \frac{[H_2O]^2}{[O_2]^3}$

130 F2 Consider the following equilibrium:

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$$

The ratio used to calculate the <u>equilibrium constant</u> is

A. $\frac{[2CO]^2[O_2]}{[2CO_2]^2}$

B. $\frac{[2CO_2]^2}{[2CO]^2[O_2]}$

C. $\frac{[CO]^2[O_2]}{[CO_2]^2}$

D. $\frac{[CO_2]^2}{[CO]^2[O_2]}$

131 F2 Consider the following equilibrium:

$$I_{2(s)} + H_2O_{(\ell)} \rightleftarrows H^+_{(aq)} + I^-_{(aq)} + HOI_{(aq)}$$

The equilibrium constant expression for the above system is…..

A. $K_{eq} = [H^+][I^-]$

B. $K_{eq} = [H^+][I^-][HOI]$

C. $K_{eq} = \frac{[H^+][I^-][HOI]}{[I_2][H_2O]}$

D. $K_{eq} = \frac{[H^+][I^-][HOI]}{[H_2O]}$

132 F2 **The <u>equilibrium constant expression</u> for the reaction below is….**

$$2Hg_{(l)} + O_{2(g)} \rightleftarrows 2HgO_{(s)}$$

A. $K_{eq} = \frac{1}{[O_2]}$

B. $K_{eq} = [O_2]$

C. $K_{eq} = \frac{[2HgO]}{[O_2][2Hg]}$

D. $K_{eq} = \frac{[HgO]^2}{[Hg]^2[O_2]}$

133 F2 Consider the following equilibrium system:

$$SnO_{2(s)} + 2CO_{(g)} \rightleftarrows Sn_{(s)} + 2CO_{2(g)}$$

The <u>equilibrium constant expression</u> for the above system is….

A. $K_{eq} = \frac{[CO_2]^2}{[CO]^2}$

B. $K_{eq} = \frac{[2CO_2]^2}{[2CO]^2}$

C. $K_{eq} = \frac{[CO_2]^2\ [Sn]}{[CO]^2\,[SnO_2]}$

D. $K_{eq} = \frac{[2CO_2]^2\ [Sn]}{[2CO]^2\,[SnO_2]}$

134 F2 Consider the following equilibrium constant expression:

$$K_{eq} = [CO_2]$$

Which one of the following <u>equilibrium systems</u> does the above <u>expression</u> represent?

A. $CO_{2(g)} \rightleftarrows CO_{2(s)}$

B. $PbO_{(s)} + CO_{2(g)} \rightleftarrows PbCO_{3(s)}$

C. $CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)}$

D. $H_2CO_{3(aq)} \rightleftarrows H_2O_{(l)} + CO_{2(aq)}$

135 F2 **What is the <u>K_{eq} expression</u> for** AUG 2000

$$Sb^{3+}_{(aq)} + Cl^-_{(aq)} + H_2O_{(\ell)} \rightleftarrows SbOCl_{(s)} + 2H^+_{(aq)}$$

A. $K_{eq} = \frac{[H^+]^2}{[Sb^{3+}][Cl^-]}$

B. $K_{eq} = \frac{[H^+]^2[SbOCl]}{[Sb^{3+}][Cl^-]}$

C. $K_{eq} = \frac{[H^+]^2}{[Sb^{3+}][Cl^-][H_2O]}$

D. $K_{eq} = \frac{[H^+]^2[SbOCl]}{[Sb^{3+}][Cl^-][H_2O]}$

136 F2 The equilibrium expression for a reaction is……

$$K_{eq} = \frac{[H^+]^6}{[Bi^{3+}]^2[H_2S]^3}$$

The reaction could be:

A. $6H^+_{(aq)} + BiS_{(s)} \rightleftarrows 2Bi^{3+}_{(aq)} + 3H_2S_{(g)}$

B. $6H^+_{(aq)} + Bi_2S_{3(s)} \rightleftarrows 2Bi^{3+}_{(aq)} + 3H_2S_{(g)}$

C. $2Bi^{3+}_{(aq)} + 3H_2S_{(aq)} \rightleftarrows Bi_2S_{3(s)} + 6H^+_{(aq)}$

D. $2Bi^{3+}_{(aq)} + 3H_2S_{(aq)} \rightleftarrows Bi_2S_{3(aq)} + 6H^+_{(aq)}$

137 F2 What is the K_{eq} expression for the following reaction?

$$SnO_{2(s)} + 2CO_{(g)} \rightleftarrows Sn_{(s)} + 2CO_{2(g)}$$

A. $K_{eq} = \frac{[CO_2]}{[CO]}$

B. $K_{eq} = \frac{[CO_2]^2}{[CO]^2}$

C. $K_{eq} = \frac{[Sn][CO_2]^2}{[CO]^2}$

D. $K_{eq} = \frac{[Sn][CO_2]^2}{[SnO_2][CO]^2}$

138 F2 **What is the K_{eq} <u>expression</u> for the following equilibrium?**

$$3Fe_{(s)} + 4H_2O_{(g)} \rightleftarrows Fe_3O_{4(s)} + 4H_{2(g)}$$

A. $K_{eq} = [H_2]^4$

B. $K_{eq} = \frac{[H_2]}{[H_2O]}$

C. $K_{eq} = \frac{[H_2]^4}{[H_2O]^4}$

D. $K_{eq} = \frac{[Fe_3O_4][H_2]^4}{[Fe]^3[H_2O]^4}$

139 F3 Consider the following equilibrium:

$$2NO_{(g)} + 2H_{2(g)} \rightleftarrows N_{2(g)} + 2H_2O_{(g)} \qquad K_{eq} = 1.3 \times 10^2$$

A 1.0 L container is initially filled with 1.0 mol of each of the species in the reaction. <u>The equilibrium shifts to the:</u>

A. left because Trial $K_{eq} > K_{eq}$ B. left because Trial $K_{eq} < K_{eq}$

C. right because Trial $K_{eq} > K_{eq}$ D. right because Trial $K_{eq} < K_{eq}$

140 F3 **Identify the equilibrium system that <u>least</u> favors the formation of products**.

A. $2HgO_{(s)} \rightleftarrows 2Hg_{(l)} + O_{2(g)}$ $K_{eq} = 1.2 \times 10^{-22}$

B. $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$ $K_{eq} = 1.8 \times 10^{-5}$

C. $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 6.5 \times 10^5$

D. $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)}$ $K_{eq} = 1.8 \times 10^{33}$

141 F3 **<u>Products are favoured</u> in an equilibrium reaction when the**

A. reaction is endothermic
B. equilibrium constant is large.
C. macroscopic properties are constant
D. activation energy of the forward reaction is high.

142 F3 Hydrogen gas dissociates into atomic hydrogen as follows:

$$H_{2(g)} \rightleftarrows 2H_{(g)} \qquad K_{eq} = 1.2 \times 10^{-71}$$

The value of the <u>equilibrium constant</u> for the above system indicates that

A. the reaction rate is very slow
B. the equilibrium is exothermic.
C. reactants are favoured at equilibrium
D. a catalyst is necessary to establish equilibrium.

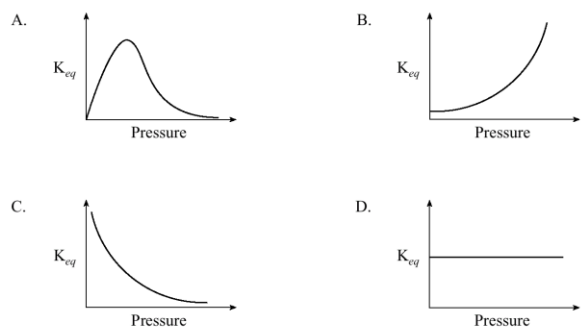
143 F3 **For an exothermic reaction at equilibrium, an <u>increase in temperature</u> will cause the equilibrium to shift**

A. left and K_{eq} increases.
B. left and K_{eq} decreases.
C. right and K_{eq} increases
D. right and K_{eq} decreases.

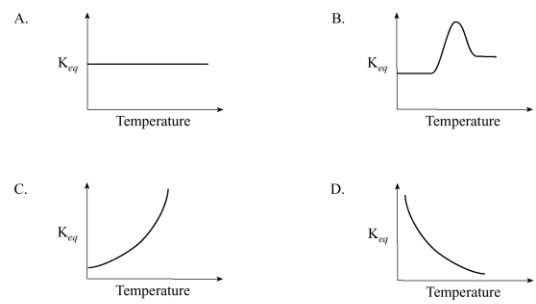
144 F4 **The value of K_{eq} changes when**

A. a catalyst is added.
B. the temperature changes.
C. the surface area changes.
D. the concentration of reactants changes.

145 F4 The relationship between K_{eq} and the pressure of a gaseous equilibrium at constant temperature can be described by



146 F4 **Which of the following best describes the relationship between <u>K_{eq} and temperature for an endothermic reaction</u>?**



147 F4 Consider the following equilibrium:

$$\text{energy} + SbCl_{5(g)} \rightleftarrows SbCl_{3(g)} + Cl_{2(g)}$$

<u>The K_{eq} decreases when</u>

A. $SbCl_5$ is added.
B. $SbCl_5$ is removed.
C. the temperature is increased.
D. the temperature is decreased.

148 F4 **The value of K_{eq} can be <u>changed</u> by**

A. adding a catalyst.
B. changing the temperature.
C. changing the reactant concentration.
D. changing the volume of the container.

149 F4 Consider the following equilibrium:

$$CaCO_{3(s)} + 556\ kJ \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

The value of the <u>equilibrium constant will increase</u> when
A. CO_2 is added. B. $CO_2$is removed.
C. the temperature is increased. D. the temperature is decreased.

150 F4 Consider the following equilibrium:

$$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)}$$

At constant temperature and volume, <u>Cl_2 is added</u> to the above equilibrium system.
As equilibrium <u>reestablishes</u>, the
A. K_{eq} will increase. B. K_{eq} will decrease. C. [NO] will increase. D. [NOCl] will increase.

151 F4 **In an exothermic equilibrium reaction involving only gases, the value of K_{eq} can be <u>decreased</u> by**
A. adding some reactant gas. B. removing some reactant gas.
C. increasing the temperature. D. decreasing the temperature.

152 F4 Consider the following equilibrium system:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \qquad \Delta H = -18\ kJ$$

In order to increase the value of K_{eq} for this reaction, you could
A. increase [CO] B. increase the volume C. decrease [CH_3OH] D. decrease the temperature

153 F4 **The temperature of an <u>exothermic</u> reaction <u>at equilibrium</u> is increased by 10° C. The value of K_{eq}**
A. doubles B. increases C. decreases D. remains constant.

154 F4 Consider the following equilibrium:

$$\underset{(pink)}{Co(H_2O)_{6\,(aq)}^{2+}} + 4Cl^-_{(aq)} \rightleftarrows \underset{(blue)}{CoCl_{4\,(aq)}^{2-}} + 6H_2O_{(\ell)}$$

When the <u>temperature is increased</u>, the solution turns a dark blue. Based on this observation, the reaction is
A. exothermic and the K_{eq} has increased. B. exothermic and the K_{eq} has decreased.
C. endothermic and the K_{eq} has increased. D. endothermic and the K_{eq} has decreased.

155 F4 Consider the following reaction:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)} \qquad \Delta H = -74.8\ kJ$$

Which of the following will cause an <u>increase</u> in the value of K_{eq} ?
A. increasing [H_2] B. decreasing the volume
C. finely powdering the $C_{(s)}$ D. decreasing the temperature

156 F4 Consider the following equilibrium:

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

When the temperature decreases, the equilibrium
A. shifts left and K_{eq} value increases.
B. shifts left and K_{eq} value decreases.
C. shifts right and K_{eq} value increases.
D. shifts right and K_{eq} value decreases.

157 F4 Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \qquad \Delta H = +181\ kJ$$

When the <u>temperature is decreased</u>, the equilibrium
A. shifts left and the K_{eq} value increases. B. shifts left and the K_{eq} value decreases.
C. shifts right and the K_{eq} value increases. D. shifts right and the K_{eq} value decreases.

158 F4 Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + 91\ kJ$$

A change in temperature of the above system increases the value of the equilibrium constant. The <u>new state</u> of equilibrium was <u>established</u> by a shift

A. left as a result of a decrease in temperature. B. right as a result of a decrease in temperature.
C. left as a result of an increase in temperature. D. right as a result of an increase in temperature.

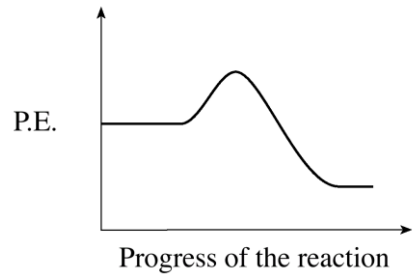
159 F4 **The value of the equilibrium constant <u>will change</u> when**

A. a catalyst is used B. temperature changes.
C. product concentrations change D. the volume of a gaseous system changes.

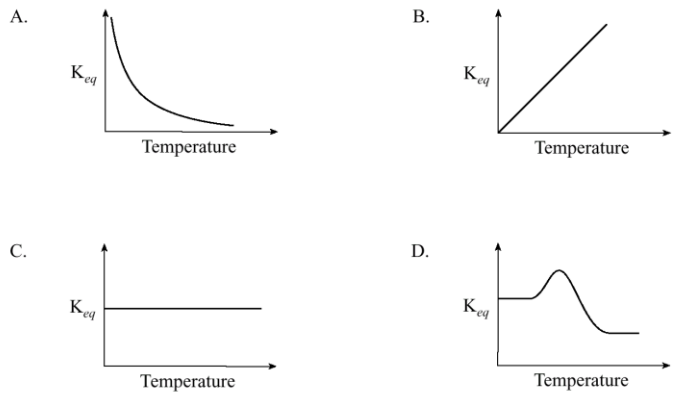
160 F4 Consider the following potential energy diagram for an equilibrium system:

When the temperature of the system is <u>increased</u>, the equilibrium shifts to the

A. left and the K_{eq} increases.
B. left and the K_{eq} decreases.
C. right and the K_{eq} increases.
D. right and the K_{eq} decreases.



161 F4 **The relationship between <u>K_{eq} and temperature</u> for an <u>exothermic reaction</u> is represented by**:



162 F5 Consider the following equilibrium:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

A 1.00 L flask contains 0.0200 mol PCl_5 , 0.0500 mol PCl_3 and 0.0500 mol Cl_2 at equilibrium. The value of K_{eq} is

A. 0.125 B. 2.50 C. 5.00 D. 8.00

163 F5 Consider the following equilibrium:

A 1.00 L flask contains 0.030 mol NO 2 and 0.040 mol N 2 O 4 at equilibrium. <u>The value of K_{eq} is</u>

A. 0.023 B. 0.67 C. 1.3 D. 44

164 F5 Consider the following:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)}$$

At equilibrium in a 1.0 L container, there are 1.60 x 10^{-2} mol C, 1.50 x10^{-2} mol H_2O, 3.00 x10^{-1} mol CO, and 1.00 x10^{-1} mol H_2 . <u>The value of K_{eq} is</u>

A. 0. 500 B. 2.00 C. 80.0 D. 125

165 F5 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

At equilibrium the $[H_2]$ =0. 020 mol/L, $[I_2]$ =0. 020 mol/L and [HI]=0.160 mol/L.
The value of the <u>equilibrium constant</u> is…
A. 2.5×10^{-3} B. 1.6×10^{-2} C. 6.4×10^{1} D. 4.0×10^{2}

166 F5 Consider the following equilibrium:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)}$$

The contents of a 1.00 L container at equilibrium were analyzed and found to contain 0.20 mol C, 0.20 mol H_2O, 0.60 mol CO and 0.60 mol H_2 . The <u>equilibrium constant</u> is..
A. 0.11 B. 0.56 C. 1.8 D. 9.0

167 F5 Consider the following equilibrium:

$$H_{2(g)} + S_{(s)} \rightleftarrows H_2S_{(g)}$$

In a 1.0 L container at equilibrium there are 0.050 mol H_2 , 0.050 mol S and 1.0 mol H_2S.
The value of K_{eq} is
A. 2.5×10^{-3} B. 5.0×10^{-2} C. 2.0×10^{1} D. 4.0×10^{2}

168 F5 Consider the following system and concentrations at equilibrium:

$$2NO_{(g)} + Br_{2(g)} \rightleftarrows 2NOBr_{(g)}$$

Substance	Equilibrium Concentration
NO	1.2×10^{-2} mol/L
Br_2	3.4×10^{-2} mol/L
NOBr	5.8×10^{-1} mol/L

What is the value of K_{eq} for the above system?
A. 1.5×10^{-5} B. 8.2×10^{2}
C. 1.4×10^{3} D. 6.9×10^{4}

169 F5 Consider the following equilibrium system:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

At equilibrium, $[PCl_5]$ is 0.400M, $[PCl_3]$ is 1.50M and $[Cl_2]$ is 0.600M. **The K_{eq} for the reaction is**

A. 0.360 B. 0.444 C. 0.900 D. 2.25

170 F5 Consider the following equilibrium system at 25° C:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$

At equilibrium, $[SO_2]$ is 4.00×10^{-3} mol/L, $[O_2]$ is 4.00×10^{-3} mol/L and $[SO_3]$ is 2.33×10^{-3} mol/L. From this data, **the K_{eq} value for the above system is**

A. 6.85×10^{-3} B. 1.18×10^{-2} C. 84.8 D. 146

171 F5 Consider the following equilibrium system:

$$CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$$

At equilibrium, a 2.0 litre sample was found to contain 1.00 mol CO, 0.500 mol Cl_2 and 0.100 mol $COCl_2$. **The K_{eq} value for the above system is**
A. 0.40 B. 0.20 C. 2.5 D. 5.0

172 F5 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

At equilibrium $[H_2] = 0.00220\ \text{mol/L}$, $[I_2] = 0.00220\ \text{mol/L}$ and $[HI] = 0.0156\ \text{mol/L}$.
The value of K_{eq} is

A. 3.10×10^{-4}

B. 1.99×10^{-2}

C. 5.03×10^{1}

D. 3.22×10^{3}

173 F6 Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

When 0.40 mol of PCl_3 and 0.40 mol of Cl_2 are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mol of PCl_5 are present. From this information, <u>the value of K_{eq}</u> is

A. 0.10 B. 0.30 C. 3.3 D. 10

174 F6 Consider the following:

$$2C_{(s)} + O_{2(g)} \rightleftarrows 2CO_{(g)}$$

A 1.00 L flask is <u>initially</u> filled with 2.00 mol C and 0.500 mol O_2 . At equilibrium, the $[O_2]$ is 0.250 mol/L. The K_{eq} value is

A. 0.444 B. 1.00 C. 2.00 D. 2.25

175 F7 Consider the following equilibrium:

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

Initially, 0.100 mol HBr is placed into a 2.0 L container. At equilibrium, there are 0.040 mol HBr present. <u>The equilibrium concentration of H_2 is</u>

A. 0.0050 mol/L B. 0.010 mol/L C. 0.015 mol/L D. 0.030 mol/L

176 F7 Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

A 1.00 L container is initially filled with 0.200 mol N_2O_4 . At equilibrium, 0.160 mol NO_2 are present. <u>What is the equilibrium concentration of N_2O_4</u>?

A. 0. 040 mol/L B. 0. 080 mol/L C. 0.120 mol/L D. 0.160 mol/L

177 F7 * Consider the following equilibrium:

$$2NOBr_{(g)} \rightleftarrows 2NO_{(g)} + Br_{2(g)} \qquad K_{eq} = 6.4 \times 10^{-2}$$

At equilibrium, a 1.00 L flask contains 0.030 mol NOBr and 0.030 mol NO.
<u>How many mol Br_2 are present?</u>

A. 1.9×10^{-3} mol B. 6.4×10^{-2} mol C. 3.0×10^{-2} mol D. 4.7×10^{-1} mol

178 F7 * Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \qquad K_{eq} = 12.0$$

At equilibrium, a 1.00 L flask contains 0.020 mol CO and 0.35 mol H_2 .
What is the <u>concentration of CH_3OH</u> at equilibrium?

A. 2.0 x 10^{-4} mol/L B. 5. 8 x 10^{-4} mol/L C. 2.9 x 10^{-2} mol/L D. 8.4 x 10^{-2} mol/L

179 F7 * Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 1.0 \times 10^{-2}$$

At equilibrium, the $[NO_2]$ =2.0 x10^{-2} mol/L and the $[N_2O_4]$ is

A. 4.0x10^{-6} mol/L B. 4.0x10^{-2} mol/L C. 2.0 mol/L D. 25 mol/L

180 F7 * Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3H_{2(g)} \qquad K_{eq} = 5.7$$

At equilibrium, the $[CH_4] = 0.40$ mol/L, $[CO] = 0.30$ mol/L and $[H_2] = 0.80$ mol/L.
The $[H_2O]$ is

A. 0.067 mol/L
B. 0.11 mol/L
C. 2.2 mol/L
D. 5.3 mol/L

181 F7 * Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 4.61 \times 10^{-3}$$

A 1.00 L container at equilibrium was analyzed and found to contain 0.0200 mol NO_2 .
At <u>equilibrium</u>, the concentration of N_2O_4 is
A. 0. 0868 mol/L B. 0. 230 mol/L C. 4.34 mol/L D. 11.5 mol/L

182 F7 * Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 0.133$$

<u>At equilibrium</u>, the $[N_2O_4]$ is equal to…..

A. $\frac{0.133}{[NO_2]}$ B. $\frac{[NO_2]}{0.133}$

C. $\frac{0.133}{[NO_2]^2}$ D. $\frac{[NO_2]^2}{0.133}$

183 F7 * Consider the following equilibrium:

$$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)} \qquad K_{eq} = 12$$

At equilibrium, [NOCl]=1.60 mol/L and [NO]=0.80 mol/L. The $[Cl_2]$ is..
A. 0.17 mol/L B. 0. 27 mol/L C. 0. 33 mol/L D. 3. 0 mol/L

184 F7 * Consider the following equilibrium system:

$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 65$$

At equilibrium, the [NO] = 0.600 M and the $[O_2]$ = 0.300 M. **Using this data, the <u>equilibrium</u> $[NO_2]$ is:**
A. 7.0 M B. 3.4 M C. 2.6 M D. 0.60 M

185 F7 * Consider the following equilibrium: *AUG 2000*

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} \qquad K_{eq} = 1.15$$

The equilibrium concentration of NO_2 is 0.50 mol/L. **Calculate the equilibrium concentration of $N_2O_{4(g)}$**

A. 0.22 mol/L B. 0.29 mol/L C. 0.43mol/L D. 0.58mol/L

186 F7 * Consider the following equilibrium:

$$2O_{3(g)} \rightleftarrows 3O_{2(g)} \qquad K_{eq} = 36$$

What is the concentration of O_3 when the equilibrium concentration of O_2 is 6.0×10^{-2} mol/L?

A. 2.4×10^{-3} mol/L
B. 4.0×10^{-2} mol/L
C. 6.0×10^{-2} mol/L
D. 9.0×10^{-2} mol/L

187 F8 Consider the following equilibrium:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)} \qquad K_{eq} = 2.30$$

A 1.0 L container is filled with 0.05 mol PCl_5 , 1.0 mol PCl_3 , and 1.0 mol Cl_2 . The system <u>proceeds</u> to the

A. left because Trial $K_{eq} > K_{eq}$ B. left because Trial $K_{eq} < K_{eq}$
C. right because Trial $K_{eq} > K_{eq}$ D. right because Trial $K_{eq} < K_{eq}$

188 F8 Consider the following equilibrium:

$$H_2O_{(g)} + Cl_2O_{(g)} \rightleftarrows 2HOCl_{(g)} \qquad K_{eq} = 9.0 \times 10^{-2}$$

A 1.0 L flask contains a mixture of 1.8 x10^{-1} mol H_2O, 4.0 x10^{-4} mol Cl_2O, and 8.0x10^{-2} mol HOCl. To <u>establish equilibrium</u>, the system will proceed to the

A. left because Trial $K_{eq} > K_{eq}$ B. left because Trial $K_{eq} < K_{eq}$
C. right because Trial $K_{eq} > K_{eq}$ D. right because Trial $K_{eq} < K_{eq}$

189 F8 Consider the following equilibrium:

$$2O_{3(g)} \rightleftarrows 3O_{2(g)} \qquad K_{eq} = 55$$

If 0.060 mol of O_3 and 0.70 mol of O_2 are introduced into a 1.0 L vessel, the

A. $K_{trial} > K_{eq}$ and the $[O_2]$ increases.
B. $K_{trial} < K_{eq}$ and the $[O_2]$ increases.
C. $K_{trial} > K_{eq}$ and the $[O_2]$ decreases.
D. $K_{trial} < K_{eq}$ and the $[O_2]$ decreases.

190 F8 Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \qquad K_{eq} = 0.010$$

<u>Initially</u>, a 1.0 L container is filled with 0.40 mol of N_2 , 0.10 mol of O_2 and 0.080 mol of NO. As the system <u>approaches</u> equilibrium the

A. [NO] , [N_2] and [O_2] remain unchanged.
B. [NO] increases and both [N_2] and [O_2] decrease.
C. [NO] decreases and both [N_2] and [O_2] increase.
D. [NO] decreases and both [N_2] and [O_2] remain unchanged.

191 F8 Consider the following:

$$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} \qquad K_{eq} = 1.20$$

A 1.0 L flask is filled with 1.4 mol NO_2 and 2.0 mol N_2O_4 . <u>To reach equilibrium</u>, the reaction proceeds to the

A. left as Trial $K_{eq} > K_{eq}$ B. left as Trial $K_{eq} < K_{eq}$
C. right as Trial $K_{eq} > K_{eq}$ D. right as Trial $K_{eq} < K_{eq}$

192 F8 Consider the following equilibrium:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)} \qquad K_{eq} = 33.3$$

<u>Predict what will occur</u> when 2.0 mol of PCl_5 , 3.0 mol of PCl_3 and 4.0 mol of Cl_2 are placed in a 1.0 L container and allowed to establish equilibrium.

A. [PCl_5] will increase B. [PCl_3] and [Cl_2] will both increase
C. [PCl_5] and [Cl_2] will both increase D. [PCl_5] and [PCl_3] will both decrease

193 F8 Consider the following equilibrium system:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad K_{eq} = 4.0$$

In an experiment, 0.40 mol $SO_{2(g)}$, 0.20 mol $O_{2(g)}$ and 0.40 mol $SO_{3(g)}$ are placed into a 1.0 litre container. Which of the following statements relates the changes in [SO_2] and [O_2] as equilibrium becomes established?

A. The [SO_2]and [O_2] increase. B. The [SO_2] and [O_2] decrease.
C. The [SO_2] and [O_2] do not change D. The [SO_2]increases and the [O_2] decreases.

194 F8

AUG 2000

Consider the following equilibrium:

$$2NOCl_{(g)} \rightleftarrows 2NO_{(g)} + Cl_{2(g)}$$

A flask is filled with NOCl, NO and Cl_2. Initially there was a total of 5.0 moles of gases present. When equilibrium is reached, there is a total of 6.0 moles of gases present. Which of the following explains this observation?

A. The reaction proceeded left because the Trial $K_{eq} > K_{eq}$
B. The reaction proceeded left because the Trial $K_{eq} < K_{eq}$
C. The reaction proceeded right because the Trial $K_{eq} > K_{eq}$
D. The reaction proceeded right because the Trial $K_{eq} < K_{eq}$

195 F8 Consider the following equilibrium:

$$2NOCl_{(g)} \rightleftarrows 2NO_{(g)} + Cl_{2(g)}$$

A flask of fixed volume is initially filled with $NOCl_{(g)}$, $NO_{(g)}$, and $Cl_{2(g)}$. When equilibrium is reached, the <u>pressure has increased</u>. <u>To reach equilibrium</u>, the reaction proceeded to the

A. left because Trial K_{eq} was less than K_{eq}
B. right because Trial K_{eq} was less than K_{eq}
C. left because Trial K_{eq} was greater than K_{eq}
D. right because Trial K_{eq} was greater than K_{eq}

ANSWERS TO MULTIPLE CHOICE QUESTIONS:

INTRODUCTION

1. B
2. A
3. C
4. C
5. C
6. D
7. B
8. C
9. C
10. D
11. A
12. B
13. D
14. C
15. A
16. C
17. D
18. B
19. B
20. D
21. C
22. B
23. D
24. D
25. D
26. D
27. C
28. D
29. C
30. C
31. C
32. D
33. B
34. C
35. A
36. C
37. D
38. B
39. A
40. B
41. A
42. D
43. A
44. D
45. C
46. A
47. C
48. C

LE CHATELIER'S PRINCIPLE

49. A
50. C
51. C
52. C
53. C
54. B
55. C
56. A
57. B
58. B
59. B
60. B
61. B
62. A
63. A
64. D
65. D
66. D
67. A
68. A
69. B
70. C
71. B
72. A
73. A
74. A
75. D
76. C
77. C
78. A
79. C
80. C
81. B
82. D
83. C
84. A
85. A
86. A
87. B
88. B
89. B
90. D
91. B
92. B
93. A
94. C
95. D
96. C
97. B
98. A
99. B
100. C

THE EQUILIBRIUM CONSTANT

101. D
102. A
103. A
104. D
105. A
106. B
107. A
108. B
109. A
110. C
111. C
112. C
113. A
114. B
115. C
116. B
117. A
118. A
119. A
120. B

121. A	**136. C**	**151. C**	**166. C**	**181. A**
122. D	**137. B**	**152. D**	**167. C**	**182. D**
123. B	**138. C**	**153. C**	**168. D**	**183. C**
124. B	**139. D**	**154. C**	**169. D**	**184. C**
125. B	**140. A**	**155. D**	**170. C**	**185. B**
126. C	**141. B**	**156. B**	**171. A**	**186. A**
127. D	**142. C**	**157. B**	**172. C**	**187. A**
128. C	**143. B**	**158. B**	**173. D**	**188. A**
129. B	**144. B**	**159. B**	**174. B**	**189. C**
130. D	**145. D**	**160. B**	**175. C**	**190. C**
131. B	**146. C**	**161. A**	**176. C**	**191. D**
132. A	**147. D**	**162. A**	**177. B**	**192. B**
133. A	**148. B**	**163. D**	**178. C**	**193. A**
134. C	**149. C**	**164. B**	**179. B**	**194. D**
135. A	**150. D**	**165. C**	**180. A**	**195. B**

DYNAMIC EQUILIBRIUM STUDY GUIDE 2000

written

INTRODUCTION TO EQUILIBRIUM

D3 1 Consider the following equilibrium:

$$2\mathrm{NOCl}_{(g)} \rightleftarrows 2\mathrm{NO}_{(g)} + \mathrm{Cl}_{2(g)}$$

A chemist places 2.00 mol NOCl in a 1.0 L container. Describe the changes in [NOCl] and [Cl_2] as the system approaches equilibrium. **(1mark)**

D4 2 Identify four characteristics of a chemical equilibrium. **(2 marks)**

D4 3 What is "equal" in a chemical reaction that has reached a state of equilibrium? **2 marks**

D5 4 a) Why are chemical equilibria referred to as dynamic? **(1 mark)**
b) How is a chemical system at equilibrium recognized? **(1 mark)**

D7 5 Consider the following equilibrium:

$$4\mathrm{HCl}_{(g)} + \mathrm{O}_{2(g)} \rightleftarrows 2\mathrm{H_2O}_{(g)} + 2\mathrm{Cl}_{2(g)} + \text{energy}$$

a) How does the **entropy** change in the forward direction? Explain your reasoning. **(1 mark)**
b) How does the **enthalpy** change in the forward direction? Explain your reasoning. **(1 mark)**

D9 6 **Describe how enthalpy and entropy change**, in the forward direction, as an exothermic reaction reaches equilibrium. **Explain your reasoning**. **(2 marks)**

LE CHATELIER'S PRINCIPLE

E1 7 State Le Chatelier's Principle. **(2 marks)**

E1 8 State Le Chatelier's Principle. **(2 marks)**

E2 9 Consider the following equilibrium:

$$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)} \qquad \Delta H = -77\ kJ$$

What happens to the amount of Cl_2 when the following changes are imposed?
<u>Explain, using Le Chatelier's principle</u>.
a) Removing $NO_{(g)}$. **(1 mark)**
b) Decreasing the temperature. **(1 mark)**

E2 10 Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \qquad \Delta H = -18\ kJ$$

Explain, using Le Chatelier's principle, how the following changes will affect the number of moles of CH_3OH present at equilibrium.
a) Adding a catalyst. **(1 mark)**
b) Decreasing the volume of the system. **(1 mark)**

E2 11 Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)} \qquad \Delta H = -88\ kJ$$

What happens to the $[PCl_3]$ when additional Cl_2 is added at constant temperature and volume? Explain. **(2marks)**

E2 12 Consider the following equilibrium:

$$\underset{\text{yellow}}{2CrO_4^{2-}{}_{(aq)}} + H_2O_{(\ell)} \rightleftarrows \underset{\text{orange}}{Cr_2O_7^{2-}{}_{(aq)}} + 2OH^-{}_{(aq)}$$

When HCl is added drop-by-drop to the yellow solution above, the solution turns orange. Explain why this colour change occurs. **(2marks)**

E2 13 Consider the following equilibrium:

$$N_2H_{4(g)} + 2O_{2(g)} \rightleftarrows 2NO_{(g)} + 2H_2O_{(g)}$$

More oxygen is added to the above equilibrium. After the system re-establishes equilibrium, identify the substance(s), if any, that have a net **(2 marks)**
a) increase in concentration. _____
b) decrease in concentration. _____

E2 14 Consider the following equilibrium system:

$$\underset{\text{yellow}}{Fe^{3+}{}_{(aq)}} + \underset{\text{colourless}}{SCN^-{}_{(aq)}} \rightleftarrows \underset{\text{red}}{FeSCN^{2+}{}_{(aq)}}$$

In an experiment, a student places the above equilibrium system into a cold water bath and notes that the intensity of the red colour increases. The student then concludes that the equilibrium is exothermic.
a) Do you agree or disagree? **0.5 mark**
b) Explain: **1.5 marks**

E2 15 Consider the following reaction: **AUG 2000**

$$\underset{\text{yellow}}{Fe^{3+}{}_{(aq)}} + \underset{\text{colourless}}{SCN^-{}_{(aq)}} \rightleftarrows \underset{\text{red}}{FeSCN^{2+}{}_{(aq)}}$$

When a few drops of $6.0\,M$ NaOH is added to $25.0\,mL$ of the above system, a precipitate of $Fe(OH)_3$ forms and the solution turns pale yellow.

a) Explain this colour change in terms of Le Chatelier's Principle. **(2marks)**
b) Describe the effect on the rate of the reverse reaction as the colour change occurs. **(1mark)**

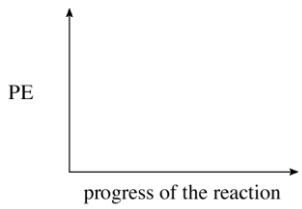
E2 16 Consider the observations for the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

(colourless) (brown)

Trial	Temperature °C	Colour
I.	10	light brown
II.	50	dark brown

a) Sketch the potential energy curve on the graph below for this equilibrium. **(1mark)**



b) Explain the colour change using Le Ch›telier's Principle. **(1mark)**
c) Other than changing temperature, what could be done to cause a shift to the left? **(1mark)**

E2 17 Methanol, CH_3OH, is produced industrially by the following reaction:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{heat}$$

a) State **two** different methods of shifting the equilibrium to the right. **(1 mark)**
b) In terms of rates, explain why these methods cause the equilibrium to shift to the right. **(1mark)**

E3 18 Consider the following equilibrium:

$$2H_2O_{(g)} \rightleftarrows 2H_{2(g)} + O_{2(g)}$$

Identify **<u>two ways</u>** to increase the rate of the **forward** reaction. **(2marks)**

E3 19 Consider the following equilibrium:

$$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$$

(yellow) (blue)

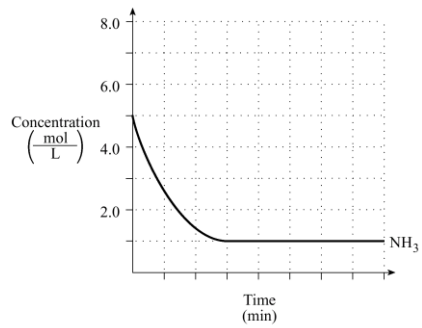
The system is yellow and turns blue on the addition of NaOH. In terms of the forward and reverse reaction rates, explain why this shift occurs. **(2marks)**

THE EQUILIBRIUM CONSTANT

F1 20 Consider the following equilibrium system:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{energy}$$

A 1. 00 L container is filled with 5.0 mol NH_3 and the system proceeds to equilibrium as indicated by the graph.



a) Draw and label the graph for N_2 and H_2 . **(2 marks)**

b) Calculate the K_{eq} for $N_{2(g)} + 3H_{2(g)} \leftrightharpoons 2NH_{3(g)}$. **(2 marks)**

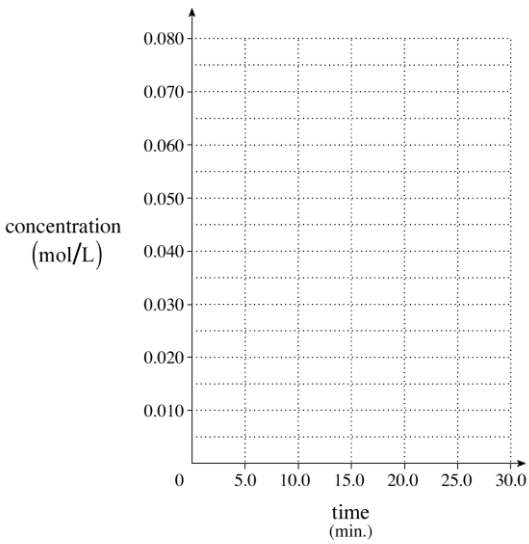
F1 21 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 64$$

Equal moles of H_2 and I_2 are placed in a 1.00 L container. At equilibrium, the [HI]=0.160 mol/L. Calculate the initial $[H_2]$. **(3 marks)**

F1 22 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$



A 2.0L container is filled with 0.070 mol of H_2 and 0.060mol of I_2. Equilibrium is reached after 15.0 minutes at which time there is 0.060 mol of HI present.

Sketch and label the graphs for the changes in concentrations of H_2, I_2, and HI for the time period of 0 to 30.0 minutes. **(3marks)**

F2 23 Consider the following equilibrium:

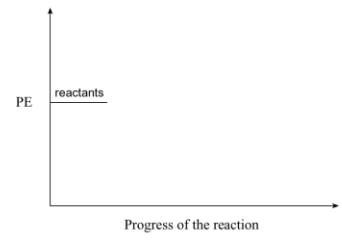
$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 6.45 \times 10^5$$

a) Write the K_{eq} expression. **(1mark)**

b) Explain why the $[NO_2]$ is greater than the [NO] at equilibrium when the $[O_2]$ is 1.0 mol/L. **(1mark)**

F4 24 Consider the following equilibrium:

$$CS_{2(g)} + 3Cl_{2(g)} \rightleftarrows CCl_{4(g)} + S_2Cl_{2(g)} \qquad \Delta H = -238\ kJ$$



a) Sketch a potential energy diagram for the reaction above and label ΔH. **(2 marks)**
b) Some CS_2 is added and equilibrium is then reestablished. State the direction of the equilibrium shift
and the resulting change in $[Cl_2]$. **(1 mark)**
c) The temperature is decreased and equilibrium is then reestablished. What will the effect be on the value of K_{eq} ? **(1 mark)**

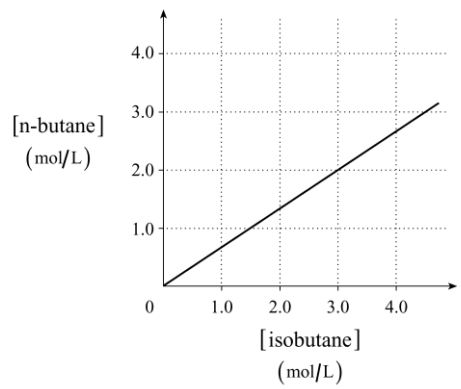
F5 25 Consider the graph below representing the following equilibrium:

$$CH_3CH_2CH_2CH_{3(g)} \rightleftarrows CH_3CH(CH_3)_{2(g)}$$

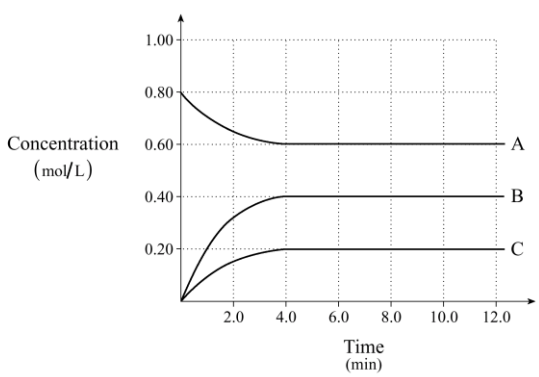
n-butane isobutane

Data for the graph was obtained from various equilibrium mixtures.

Calculate the value of K_{eq} for the equilibrium. (2 marks)



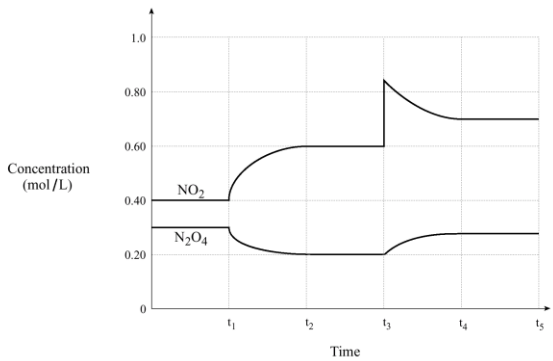
F5 26 Consider the following diagram for a chemical system containing three substances represented by A, B and C:



a) What feature of the graph indicates that the system reaches equilibrium? **(1 mark)**
b) Write a balanced equation for the equilibrium reaction. **(2 marks)**
c) Calculate K_{eq} at equilibrium. **(2 marks)**

F5 27 Consider the following graph for the reaction:

energy + $N_2O_{4\,(g)}$ ⇌ $2NO_{2\,(g)}$



a) What is the stress imposed at time t_1 ? **(1mark)**

b) What is the stress imposed at time t_3 ? **(1mark)**

c) Calculate K_{eq} for the equilibrium between t_2 and t_3 . **(2marks)**

F5 28 Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$$

At 227° C in a 2.00 L container there are 0.044 mol NO, 0.100 mol O_2 and 7.88 mol NO_2 at equilibrium. Calculate the equilibrium constant. **(3marks)**

F6 29 At high temperature, 0.500 mol HBr was placed in a 1.00 L container where it decomposed to give the equilibrium:

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

At equilibrium, the $[Br_2]$ is 0.0855 mol/L. What is the value of the equilibrium constant? **(3 marks)**

F6 30 Consider the following equilibrium:

$$2CO_{2(g)} \rightleftarrows 2CO_{(g)} + O_{2(g)}$$

Initially, a 1.0 L container is filled with 0.050 mol of CO_2 . At equilibrium, the $[CO_2]$ is 0.030 mol/L. Calculate the value of K_{eq} . **(3marks)**

F6 31 Consider the following equilibrium:

$$2CH_{4(g)} \rightleftarrows C_2H_{2(g)} + 3H_{2(g)}$$

A 0.180 mol sample of CH_4 is added to an empty 1.00 L container. At equilibrium, the $[C_2H_2]$ is 0.0800 mol/L. Calculate the equilibrium constant. **(4 marks)**

F6 32 In an experiment, 0.200 mol of $CO_{(g)}$ and 0.400 mol of $O_{2(g)}$ are placed in a 1.00 L container and the following equilibrium is achieved:

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$$

At equilibrium, the $[CO_2]$ is found to be 0.160 mol/L. Calculate the value of K_{eq} . **(3marks)**

F6 33 Given the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

Initially, 0.200 mol H_2 and 0.200 mol I_2 were placed into a 1.0 L container. At equilibrium, the $[I_2]$ is 0.040 mol/L. Calculate the K_{eq} . **(3 marks)**

F6 34 Consider the following equilibrium system:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

At 250°C, 0.40 mol of PCl_3 and 0.60 mol of Cl_2 are placed into a 1.0 litre container. At equilibrium, the $[PCl_5]$ = 0.11 mol/L. Calculate the value of K_{eq} . **(3 marks)**

F6 35 Consider the following equilibrium: **AUG 2000**

$$3I_{2(g)} + 3F_{2(g)} \rightleftarrows 2IF_{2(g)} + I_4F_{2(g)}$$

Initially, 2.00×10^{-1} mol of I_2 and 3.00×10^{-1} mol of F_2 are put into a 10.00 L flask.
At equilibrium, $[I_4F_2]$ is 2.00×10^{-3} M. Calculate the K_{eq}. **(4 marks)**

F6 36 Consider the following equilibrium:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

Initially, 50.0 mL of 0.10 M Fe^{3+} is added to 30.0 mL of 0.20 M SCN^{-}.
At equilibrium, the concentration of $FeSCN^{2+}$ is found to be 0.050 M.
Calculate the K_{eq} for the reaction. **(4 marks)**

F7 37 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 1.2 \times 10^{-2}$$

A 2.0 L flask is filled with 0.10 mol HI . Calculate the concentration of H_2 at equilibrium. **(3 marks)**

F7 38 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 49$$

A 1.00 L container is initially filled with 0.180 mol HI.
Calculate the concentration of HI at equilibrium. (4 marks)

F7 39 Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 7.1 \times 10^{2}$$

At equilibrium, the $[H_2] = 0.012$ mol/L and $[HI] = 0.40$ mol/L. What is the equilibrium concentration of I_2 ? **(2 marks)**

F7 40 Consider the following equilibrium:

$$H_{2(g)} + S_{(s)} \rightleftarrows H_2S_{(g)} \qquad K_{eq} = 6.8 \times 10^{-2}$$

A 1.0 L container is initially filled with 0.050 mol H_2 and 0.050 mol S. The container is heated to 90° C and equilibrium is established. What is the equilibrium $[H_2S]$? **(3 marks)**

F7 41 Consider the following:

$$H_{2(g)} + F_{2(g)} \rightleftarrows 2HF_{(g)} \qquad K_{eq} = 1.00 \times 10^{2}$$

A 1.00 L flask is initially filled with 2.00 mol H_2 and 2.00 mol F_2 .
Calculate the $[H_2]$ at equilibrium. **(4 marks)**

F7 42 Consider the following equilibrium:

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)} \qquad K_{eq} = 81.0$$

A 1.00 L container is initially filled with 4.00 mol HI. Calculate the [HI] at equilibrium. **(4marks)**

F7 43 Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} \qquad K_{eq} = 626 \text{ at } 200°C$$

At equilibrium, $[N_2]$ is 1.06 mol/L and $[H_2]$ is 0.456 mol/L. Calculate $[NH_3]$ in the equilibrium mixture.
(2 marks)

F7 44 Consider the data obtained for the following equilibrium:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

	$[Fe^{3+}]$	$[SCN^{-}]$	$[FeSCN^{2+}]$
Experiment 1	3.91×10^{-2}	8.02×10^{-5}	9.22×10^{-4}
Experiment 2	6.27×10^{-3}	3.65×10^{-4}	?

Calculate the $[FeSCN^{2+}]$ in experiment #2. **(3 marks)**

F8 45 Consider the following equilibrium system:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)} \qquad K_{eq} = 8.1 \times 10^{8} \text{ at } 25°C$$

A student places 4.5 mol of carbon, 3.6 x 10^{-3} mol of hydrogen and 5.1 mol of methane in a 1.0 L flask. The student predicts that the $[CH_4]$ increases as equilibrium is established. Do you agree? Explain your answer using appropriate calculations. **(3 marks)**

F8 46 Consider the following equilibrium system:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)} \qquad K_{eq} = 0.80$$

In an experiment, a student places 0.10 mol of C, 0.15 mol of H_2O, 0.25 mol of CO, and 0.20 mol of H_2 into a 1.0 L flask. The student predicts that the [CO] will decrease as equilibrium becomes established. **(3 marks)**

a) Would you agree or disagree with the student?

b) Justify your answer, including appropriate calculations.

E5 47 The production of ammonia by the Haber process involves the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{heat}$$

The table below indicates the percentage of ammonia in equilibrium mixtures at various temperatures.

Temperature °C	Percentage of Ammonia in Equilibrium
200	98
350	80
500	51

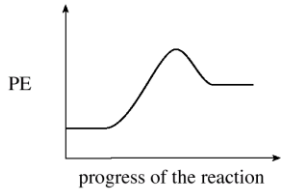
a) Explain why the lower temperature results in a higher percentage of ammonia in the equilibrium mixture. **(1 mark)**

b) Explain why a temperature of 500°C is used in the Haber process rather than a lower temperature. **(1 mark)**

EQUILIBRIUM WRITTEN SOLUTIONS (FROM PROVINCIAL KEYS)

D3	1	[NOCl] decreases as it approaches equilibrium. [Cl_2] increases as it approaches equilibrium. **1 mark**
D4	2	• Closed container. • Constant temperature. • Reversible reaction. • Both reactants and products present. • No changes in macroscopic properties. • Rate of forward reaction equals rate of reverse reaction. • Responds to imposed stresses. **any four for1/2 mark each**
D4	3	The rates of the forward and reverse reactions.
D5	4	a) Both the forward and reversed reactions continue to occur. **1mark** b) A chemical system at equilibrium is recognized by its constant macroscopic properties.**1 mark**
D7	5	a) Entropy is decreasing. Five particles of gas (reactants) have more entropy than four particles of gas (products).**1 mark** b) Enthalpy is decreasing. The reaction is exothermic, so the enthalpy of the products is less than the enthalpy of the reactants. **1 mark**
D9	6	***For Example*:** **Enthalpy:** is decreasing. **1/2 mark** **Entropy:** is decreasing. **1/2 mark** **Explanation:** Since the system reaches equilibrium, the drive to minimum enthalpy and maximum entropy must be opposing one another. **1 mark**
E1	7	When a system at equilibrium is subjected to a stress, processes occur that tend to counteract the stress and re-establish equilibrium. **2 marks**
E1	8	When a system at equilibrium(**1/2 mark**) is subjected to a stress, (**1/2 mark**) the system shifts so as to offset the stress (**1/2 mark**) and establish a new equilibrium (**1/2 mark**) .
E2	9	a) The amount of Cl_2 will increase because the equilibrium shifts left. **1 mark** b) The amount of Cl_2 will decrease because the equilibrium shifts right. **1 mark**
E2	10	a) The moles of CH_3OH will not change because the equilibrium does not shift. **1 mark** b) The moles of CH_3OH will increase because the equilibrium shifts right. **1 mark**
E2	11	The [PCl_3] decreases when additional Cl_2 is added. The addition of Cl_2 causes the equilibrium to shift right.
E2	12	HCl neutralizes OH^- $\quad H^+ + OH^- \rightarrow H_2O$ $\therefore [OH^-]$ decreases, therefore equilibrium shifts right (orange). $\leftarrow$ **2 marks**
E2	13	a) NO, H_2O, O_2 **1/2 mark each** b) N_2H_4 **1/2 mark**
E2	14	agree with student $\leftarrow$ **1/2 mark** cold water bath caused shift in forward direction $\leftarrow$ **1/2 mark** when temp. is decreased, equil shifts in exo direction **1 mark**
E2	15	a) The reduced $[Fe^{3+}]$ causes a shift to the left to offset the stress. $\leftarrow$ **2 marks** b) The rate of the reverse reaction decreases. **1 mark**

E2 16 a)



← **1 mark**

b) An increase in temperature causes the reaction to shift to the right and the NO increases. **1 mark**
c) To cause a shift to the left add NO_2 **or** remove N_2O_4 **or** decrease the volume.**1 mark**

E2 17 a) ***For Example:*** ***Any*** *two* ***of the following:***

- adding reactant
- removing methanol
- decreasing the temperature
- increasing the pressure by decreasing the volume

b) The shift occurs because rate$_{(f)}$ must be greater than rate$_{(r)}$ as a result of the stress.

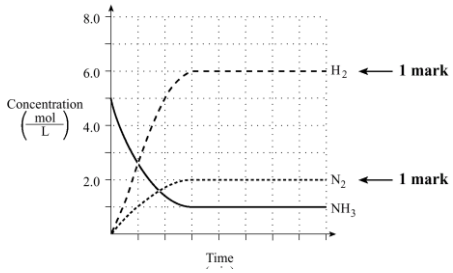
E3 18 **Two of the following:**
• Add more H_2O
• Add a catalyst
• Decrease the volume
• Increase the temperature

E3 19

Addition of OH^- decreases $[H_3O^+]$, decreasing the reverse rate. Since the forward rate is greater than the reverse rate, the system shifts to the right.

← **2 marks**

F1 20 a)



b)

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$= \frac{(1.0)^2}{(2.0)(6.0)^3}$$

$$= 2.3 \times 10^{-3}$$

F1 21

	$H_{2(g)}$	+	$I_{2(g)}$	$\rightleftarrows$	$2HI_{(g)}$
[I]	x		x		0
[C]	−0.080		−0.080		+0.160
[E]	$x-0.080$		$x-0.080$		0.160

← **1 ½ marks**

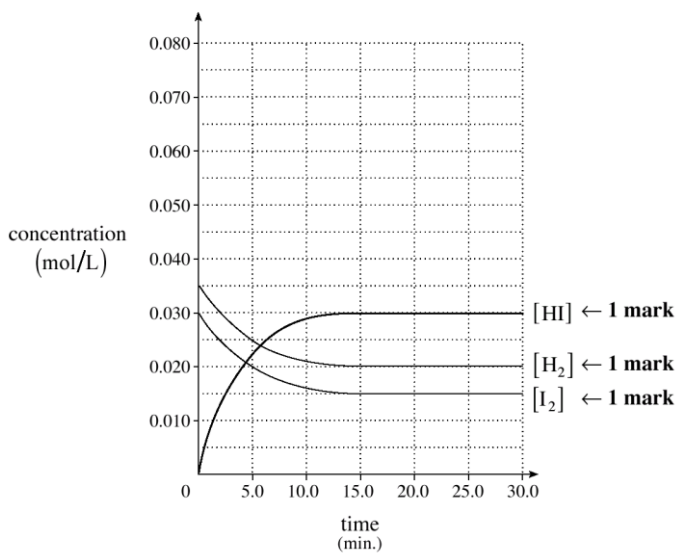
$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$64 = \frac{(0.160)^2}{(x-0.080)^2}$$

$$[H_2] = x = 0.10 \text{ mol/L}$$

← **1 ½ marks**

F1 22



Explanation of graph (not for marks).

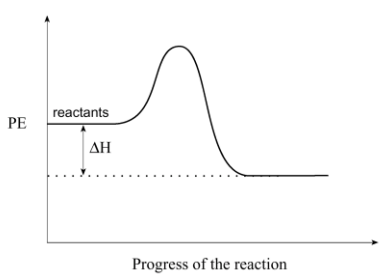
	$H_{2(g)}$	+	$I_{2(g)}$	$\rightleftarrows$	$2HI_{(g)}$
[I]	0.035 M		0.030 M		–
[C]	–0.015 M		–0.015 M		+0.030 M
[E]	0.020 M		0.015 M		0.030 M

F2 23 a)

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

b) A large K_{eq} means [products] > [reactants] .

F4 24 a)



1 mark for general shape
1 mark for ΔH

b) The equilibrium shifts to the right □**1/2 mark** □□and $[Cl_2]$ □decreases □**1/2 mark**□□.

c) K_{eq} will increase. **1 mark**

F5 25

$$K_{eq} = \frac{[\text{isobutane}]}{[\text{n - butane}]} \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$= \frac{3.0}{2.0} \quad \leftarrow \textbf{1 mark}$$

$$= 1.5 \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

F5 26 a) The concentrations become constant (1 mark)

b) A ⇌ 2B + C (2 marks)

c) (2marks)

$$K_{eq} = \frac{[B]^2[C]}{[A]} = \frac{(0.40)^2(0.20)}{0.60} = 0.053$$

F5 27 a) Temperature is increased. **1 mark**

b) NO_2 added. **1 mark**

c)

$$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.60)^2}{(0.20)} = 1.8 \quad \leftarrow \textbf{2 marks}$$

F5 28

$$2NO + O_2 \rightleftarrows 2NO_2$$

$$\left.\begin{array}{lll} \frac{0.044 \text{ mol}}{2.00 \text{ L}} & \frac{0.100 \text{ mol}}{2.00 \text{ L}} & \frac{7.88 \text{ mol}}{2.00 \text{ L}} \\ [E] = 0.022 & = 0.0500 & = 3.94 \end{array}\right\} \leftarrow \textbf{1 mark}$$

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{(3.94)^2}{(0.022)^2(0.0500)} \quad \leftarrow \textbf{1}\tfrac{1}{2} \textbf{ marks}$$

$$= 6.4 \times 10^5 \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

F6 29

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

[I]	0.500	0	0
[C]	−0.171	+0.0855	+0.0855
[E]	0.329	0.0855	0.0855

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[H_2][Br_2]}{[HBr]^2}$$

$$= \frac{(0.0855)(0.0855)}{(0.329)^2}$$

$$= 6.75 \times 10^{-2}$$

← **1 $\frac{1}{2}$ marks**

F6 30

	$2CO_2$	$\rightleftarrows$ $2CO$	+ O_2
[I]	0.050	0	0
[C]	−0.020	+0.020	+0.010
[E]	0.030	0.020	0.010

← **1 ½ marks**

$$K_{eq} = \frac{[CO]^2[O_2]}{[CO_2]^2}$$

$$= \frac{(0.020)^2(0.010)}{(0.030)^2}$$

$$= 4.4 \times 10^{-3}$$

← **1 ½ marks**

Deduct ½ mark for incorrect significant figures.

F6 31

	$2CH_{4(g)}$	$\rightleftarrows$ $C_2H_{2(g)}$	+ $3H_{2(g)}$
[I]	0.180	0	0
[C]	−0.160	+0.0800	+0.240
[E]	0.020	0.0800	0.240

← **2 marks**

$$K_{eq} = \frac{[C_2H_2][H_2]^3}{[CH_4]^2}$$

$$= \frac{(0.0800)(0.240)^3}{(0.020)^2}$$

$$= 2.8$$

← **2 marks**

F6 32

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$$

[I]	0.200	0.400	0.000
[C]	−0.160	−0.080	+0.160
[E]	0.040	0.320	0.160

← **1 ½ marks**

$$K_{eq} = \frac{[CO_2]^2}{[CO]^2[O_2]} = \frac{(0.160)^2}{(0.040)^2(0.320)}$$

$$= 5.0 \times 10^1$$

← **1 ½ marks**

F6 33

	H_2	+	I_2	$\rightleftarrows$	$2HI$
[I]	0.200 M		0.200		0
[C]	−0.160		−0.160		+0.320
[E]	0.040		0.040		0.320

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$= \frac{(0.320)^2}{(0.040)(0.040)}$$

$$= 64$$

← **1 $\frac{1}{2}$ marks**

F6 34

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

I	0.40	0.60	0.00	
C	−0.11	−0.11	+0.11	← **1 $\frac{1}{2}$ marks** for ICE
E	0.29	0.49	0.11	

$K_{eq} = [PCl_5]/[PCl_3][Cl_2]$ ← **$\frac{1}{2}$ mark**

$= (0.11)/(0.29)(0.49)$ ← **$\frac{1}{2}$ mark** for substitution

$= 0.77$ ← **$\frac{1}{2}$ mark** for final answer

F6 35

	$3I_2$	+	$3F_2$	$\rightleftarrows$	$2IF_2$	+	I_4F_2
[I]	0.0200		0.0300		0		0
[C]	−0.0060		−0.00600		+0.00400		+0.00200
[E]	0.0140		0.0240		0.00400		0.00200

1 mark for division by 10

1 $\frac{1}{2}$ marks for ICE table

$$K_{eq} = \frac{(IF_2)^2(I_4F_2)}{(I_2)^3(F_2)^3}$$

$$K_{eq} = \frac{(0.00400)^2(0.00200)}{(0.0140)^3(0.0240)^3}$$

$$= 8.44 \times 10^2$$

← **1 $\frac{1}{2}$ marks**

F6 36

$$[Fe^{3+}] = \frac{50.0\text{ mL}}{80.0\text{ mL}} \times 0.10\text{ M} = 0.0625\text{ M}$$

$$[SCN^-] = \frac{30.0\text{ mL}}{80.0\text{ mL}} \times 0.20\text{ M} = 0.0750\text{ M}$$

← **1 mark**

	Fe^{3+}	+ SCN^-	$\rightleftarrows$ $FeSCN^{2+}$
[I]	0.0625	0.0750	0
[C]	−0.0500	−0.0500	0.0500
[E]	0.0125	0.0250	0.0500

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^-]}$$

$$= \frac{0.0500}{(0.0125)(0.0250)}$$

$$= 1.6 \times 10^2$$

← **1 $\frac{1}{2}$ marks**

F7 37

	H_2 +	I_2 $\rightleftarrows$	$2HI$
[I]	0	0	0.050
[C]	$+x$	$+x$	$-2x$
[E]	x	x	$0.050 - 2x$

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 1.2 \times 10^{-2}$$

← **$\frac{1}{2}$ mark**

$$= \frac{(0.050 - 2x)^2}{x^2} = 1.2 \times 10^{-2}$$

$$= \sqrt{\frac{(0.050 - 2x)^2}{x^2}} = \sqrt{1.2 \times 10^{-2}}$$

← **$\frac{1}{2}$ mark**

$$x = [H_2] = 0.024\text{ M}$$

← **$\frac{1}{2}$ mark**

F7 38

	$H_{2(g)}$ +	$I_{2(g)}$ $\rightleftarrows$	$2HI_{(g)}$
[I]	0	0	0.180
[C]	$+x$	$+x$	$-2x$
[E]	x	x	$0.180 - 2x$

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$= \frac{(0.180 - 2x)^2}{(x)^2} = 49$$

$$x = 0.020$$

← **1 $\frac{1}{2}$ marks**

$$[HI] = 0.180 - 2x$$

$$= 0.140\text{ mol/L}$$

← **1 mark**

F7 39

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$\therefore [I_2] = \frac{[HI]^2}{[H_2]K_{eq}}$$

$$= \frac{(0.40)^2}{(0.012)(7.1\times10^2)}$$

$$= 0.019 \text{ mol/L}$$

← **2 marks**

NOTE: ($\frac{1}{2}$ mark) is deducted for incorrect significant figures.

F7 40

	$H_{2(g)}$ +	$S_{(s)}$ ⇄	$H_2S_{(g)}$
[I]	0.050		0
[C]	$-x$		$+x$
[E]	$0.050 - x$		x

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[H_2S]}{[H_2]}$$

$$6.8\times10^{-2} = \frac{(x)}{(0.050 - x)}$$

$$x = 0.0032$$

$$[H_2S] = 3.2\times10^{-3} \text{ mol/L}$$

← **1 $\frac{1}{2}$ marks**

F7 41

	$H_{2(g)}$ +	$F_{2(g)}$ ⇄	$2HF_{(g)}$
[I]	2.00	2.00	0
[C]	$-x$	$-x$	$+2x$
[E]	$2.00 - x$	$2.00 - x$	$2x$

← **1 $\frac{1}{2}$ marks**

$$K_{eq} = \frac{[HF]^2}{[H_2][F_2]}$$

$$1.00\times10^2 = \frac{(2x)^2}{(2.00 - x)^2}$$

$$x = 1.67$$

← **1 $\frac{1}{2}$ marks**

$[H_2] = 2.00 - x = 2.00 - 1.67 = 0.33$ mol/L ← **1 mark**

F7 42

	$2HI$	$\rightleftarrows$	H_2	+	I_2
[I]	4.00		0		0
[C]	$-2x$		$+x$		$+x$
[E]	$4.00-2x$		x		x

← **1 ½ marks**

$$K_{eq} = \frac{[H_2][I_2]}{[HI]^2}$$

$$\frac{x^2}{(4.00-2x)^2} = 81.0$$

$$x = 1.8947 \text{ mol/L}$$

← **1 ½ marks**

$$[HI] = 4.00 - 3.79 = 0.21 \text{ mol/L}$$

← **1 mark**

F7 43

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

← **½ mark**

$$626 = \frac{[NH_3]^2}{(1.06)(0.456)^3}$$

← **½ mark**

$$[NH_3] = 7.93$$

← **1 mark**

F7 44

$$K_{eq} = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^-]}$$

$$= \frac{9.22 \times 10^{-4}}{(3.91 \times 10^{-2})(8.02 \times 10^{-5})}$$

$$= 2.94 \times 10^2$$

← **1 ½ mark**

$$2.94 \times 10^2 = \frac{x}{(6.27 \times 10^{-3})(3.65 \times 10^{-4})}$$

$$[FeSCN^{2+}] = x = 6.73 \times 10^{-4} \text{ M}$$

← **1 ½ mark**

(Deduct **½ mark** for incorrect significant figures.)

F8 45

$$\text{Trial } K_{eq} = \frac{[CH_4]}{[H_2]^2} \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$= \frac{5.1}{\left(3.6 \times 10^{-3}\right)^2} \qquad \leftarrow \textbf{1 mark}$$

$$= 3.9 \times 10^5$$

Since Trial K_{eq} is less than the Actual K_{eq}, the forward reaction is favoured and the $[CH_4]$ increases. ← **1 mark**

Yes, I agree with the student. ← **½ mark**

Note: solutions to questions 46,47 intentionally left off the key…hmmmm?