Thermodynamics of Enzyme-Catalyzed Reactions: Part 6—1999 Update

Cite as: Journal of Physical and Chemical Reference Data **28**, 931 (1999); https://doi.org/10.1063/1.556041
Submitted: 18 February 1999 . Published Online: 03 December 1999

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Thermodynamics of Enzyme-Catalyzed Reactions: Part 6—1999 Update

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Received February 18, 1999; final revision received May 4, 1999

This review serves to update previously published evaluations of equilibrium constants and enthalpy changes for enzyme-catalyzed reactions. For each reaction the following information is given: the reference for the data; the reaction studied; the name of the enzyme used and its Enzyme Commission number; the method of measurement; the conditions of measurement [temperature, pH, ionic strength, and the buffer(s) and cofactor(s) used]; the data and an evaluation of it; and, sometimes, commentary on the data and on any corrections which have been applied to it or any calculations for which the data have been used. The data from 96 references have been examined and evaluated. Chemical Abstract Service registry numbers are given for the substances involved in these various reactions. There is also a cross reference between the substances and the Enzyme Commission numbers of the enzymes used to catalyze the reactions in which the substances participate. © *1999 American Institute of Physics and American Chemical Society.* [S0047-2689(99)00204-4]

Key words: apparent equilibrium constants; enthalpies of reaction; enzyme-catalyzed reactions; evaluated data; transformed thermodynamic properties.

Contents

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1. Introduction

This paper serves to update a series of reviews[1–5] on the thermodynamics of enzyme-catalyzed reactions. These reviews, which were published during the years 1993–1995, deal with the thermodynamics of the reactions catalyzed by the six classes of enzymes classified by the Nomenclature Committee of the International Union of Biochemistry:[6] oxidoreductases,[1] transferases,[2] hydrolases,[3] lyases,[4] isomerases,[5] and ligases.[5] The current review updates these earlier publications by providing coverage of the literature through the end of 1998. Thus, while it primarily consists of papers published since the completion of the earlier reviews,[1–5] additional papers which contain data missed previously are also included. Accordingly, it is important that anyone examining a given reaction for which data are given in this review, also consult the earlier reviews[1–5] in order to determine if more reliable results have been previously summarized.

Enzyme-catalyzed reactions play significant roles in many biological processes such as glycolysis, the anabolism and catabolism of carbohydrates, fermentation, and vision. Many of these reactions are also of current or potential importance for the production of pharmaceuticals and bulk commodity chemicals such as ethanol, fructose, and amino acids. The data presented herein are limited to equilibrium and calorimetric measurements performed on these reactions under *in vitro* conditions. Thus, the thermodynamic quantities which are generally given are apparent equilibrium constants K' and calorimetrically determined enthalpies of reaction $\Delta_r H(\mathrm{cal})$. Apparent equilibrium constants calculated from kinetic data are also tabulated. If the change in binding of hydrogen ion $\Delta_r N(\mathrm{H}^+)$ in a biochemical reaction and the enthalpy of protonation of the buffer are known, the standard transformed enthalpy of reaction $\Delta_r H'^\circ$ can be calculated from the calorimetrically determined enthalpy of reaction.[7] Equilibrium constants K and standard molar enthalpies of reaction $\Delta_r H^\circ$ for chemical reference reactions are also

given if they have been reported in the literature. The standard transformed enthalpy of reaction $\Delta_r H'^\circ$ can be used to calculate the temperature dependence of apparent equilibrium constants K' in the same way that the standard enthalpy of reaction $\Delta_r H^\circ$ is used to calculate the temperature dependence of the equilibrium constant K.

These data also serve as a basis for many additional thermodynamic calculations. Thus, Alberty[8,9] has used data given in the previous reviews[1–5] to calculate tables of standard transformed formation properties that are useful for the calculation of apparent equilibrium constants K' and standard transformed enthalpies of reaction $\Delta_r H'^\circ$ under specified conditions of temperature, pH, pMg, and ionic strength. If the prerequisite thermodynamic quantities on the binding of H^+(aq) and metal ions are available, it is also possible to calculate standard thermodynamic quantities (K and $\Delta_r H^\circ$) for reference reactions that involve specific species. Such calculations serve to transform the results of measurements made under varied conditions and that pertain to a mixture of species to results for reference reactions that pertain to the same standard state. Thus, once a sufficiently large reaction catalog has been established, thermodynamic network calculations[10] can be performed both to check the consistency of the data and to calculate ''best'' values of standard formation properties. Finally, and most importantly, these standard formation properties can then be used to calculate values of K and $\Delta_r H^\circ$ for a very large number of reactions that have not been the subject of investigation.

The data are presented in the same format as in the previous reviews.[1–5] Thus, the following information is given for each entry in this review: the reference for the data; the biochemical reaction studied; the name of the enzyme used and its Enzyme Commission number; the method of measurement; the conditions of measurement [temperature, pH, ionic strength, and the buffer(s) and cofactor(s) used]; the data and an evaluation of it; and, sometimes, commentary on the data and on any corrections which have been applied to it or any calculations for which the data have been used. The absence of a piece of information indicates that it was not found in the paper cited. The arrangement of the data, its evaluation, and the thermodynamic conventions have been discussed previously.[1] In this regard, one should express equilibrium constants as dimensionless quantities. However, the numerical value obtained for the equilibrium constant of an unsymmetrical reaction will depend upon the measure of composition and standard concentration selected for the reactants and products. Thus, for the chemical reaction

$$\mathrm{A(aq)=B(aq)+C(aq)}, \tag{1}$$

$K_c = c(\mathrm{B})c(\mathrm{C})/\{c(\mathrm{A})c^\circ\}$, $K_m = m(\mathrm{B})m(\mathrm{C})/\{m(\mathrm{A})m^\circ\}$, and $K_x = x(\mathrm{B})x(\mathrm{C})/x(\mathrm{A})$. Here, c, m, and x are, respectively, concentration, molality, and mole fraction, $c^\circ = 1\ \mathrm{mol\,dm^{-3}}$, and $m^\circ = 1\ \mathrm{mol\,kg^{-1}}$. The equilibrium constant expressed in terms of mole fractions is automatically dimensionless. Similar definitions and considerations apply to the apparent equilibrium constant K'. The symbols used in this paper are given in the Glossary (see Sec. 7).

The *subjective* evaluation of the data in this review consisted of the assignment of a rating: A (high quality), B(good), C (average), or D (low quality). In making these assignments, we considered the various experimental details which were provided in the study. These details include the method of measurement, the number of data points determined, and the extent to which the effects of varying temperature, pH, and ionic strength were investigated. A lower rating was generally given when few details of the investigation were reported. For example, in many of the papers cited, the major aim of the study was the isolation and purification of the enzyme of interest. Thus, the equilibrium data were obtained as only a small part of an investigation to characterize many of the properties of that enzyme and the reaction it catalyzes.

This effort began $\approx$10 years ago with an extensive search of the literature to locate the papers containing the relevant data. This search was based on a carefully designed computer search of Chemical Abstracts, a manual search of Methods in Enzymology, and the examination of references found in earlier reviews that dealt with the thermodynamics of enzyme-catalyzed reactions.[11–21] The references obtained from these sources were in turn examined for additional references relevant to this effort. The current update, which covers the literature through the end of 1998, relied primarily on a search of Chemical Abstracts. The author would be most grateful if references that contain data on the thermodynamics of enzyme-catalyzed reactions that were not included in these reviews were brought to his attention.

2. Acknowledgments

The author thanks Dr. Yadu B. Tewari for his comments on this article and Dr. David Vanderah for his help with some aspects of chemical nomenclature. Continuing discussions with Dr. Robert A. Alberty on various aspects of biochemical thermodynamics have been very helpful.

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4. Table of Equilibrium Constants and Enthalpies of Reaction

4.1. Enzyme: alcohol dehydrogenase (EC 1.1.1.1)

ethanol(aq)+NAD(aq)=acetaldehyde(aq)+NADH(aq)

T/K	P/MPa	pH	K'
298.15	0.1	8.8	4.23
298.15	30	8.8	2.54
298.15	60	8.8	1.84
298.15	90	8.8	1.73
298.15	120	8.8	1.33
298.15	150	8.8	1.27
308.15	0.1	8.8	1.81
308.15	30	8.8	1.98
308.15	60	8.8	1.73
308.15	90	8.8	1.60
308.15	120	8.8	1.08
308.15	150	8.8	1.22

Reference: 89JEE/SHI
Method: spectrophotometry
Buffer: Tris ($0.1\,\mathrm{mol\,dm^{-3}}$)+HCl
pH: 8.8
Evaluation: D

Jee and Shin measured the apparent equilibrium constant K' as a function of pressure P. The reported pH is that of the buffer at $P=0.1$ MPa. This may have caused a systematic error in the results since the apparent equilibrium constant is a function of pH. Also, the reported values differ significantly from several previously reported results (see for example the results of Backlin [58BAC] and Burton [74BUR] summarized by Goldberg *et al.* [93GOL/TEW]) which were judged to be reliable. Thus, the results of Jee and Shin [89JEE/SHI] are considered to be in error.

4.2. Enzyme: L-iditol 2-dehydrogenase (EC 1.1.1.14)

D-arabitol(aq)+NAD(aq)=D-ribulose(aq)+NADH(aq)

T/K	pH	K'
298.15	7.0	0.0008

Reference: 89SCH/GIF
Method: spectrophotometry
Buffer: potassium phosphate ($0.10\,\mathrm{mol\,dm^{-3}}$)
pH: 7.0
Evaluation: C

Schneider and Giffhorn reported $K'c(\mathrm{H^+})/c^\circ=8.0\cdot10^{-11}$ at pH=7.0. The apparent equilibrium constant given here was calculated from this result.

L-iditol(aq)+NAD(aq)=L-sorbose(aq)+NADH(aq)

T/K	pH	I_m / mol·kg^{-1}	K'
298.15	7.58	0.191	0.186

Reference: 96TEW/GOL
Method: HPLC and spectrophotometry
Buffer: phosphate
pH: 7.58
Evaluation: A

Tewari and Goldberg also calculated $K=2.02\cdot10^{-9}$ and $\Delta_rH^\circ=14.7\,\mathrm{kJ\,mol^{-1}}$ at $T=298.15$ K and $I=0$ for the reference reaction: L-iditol(aq)+$\mathrm{NAD^-}$(aq)=L-sorbose(aq)+$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

L-iditol(aq)+NAD(aq)=L-sorbose(aq)+NADH(aq)

T/K	pH	I_m / mol·kg^{-1}	Δ_rH(cal) / kJ·mol^{-1}
298.15	7.39	0.215	−10.5

Reference: 96TEW/GOL
Method: calorimetry
Buffer: phosphate
pH: 7.39
Evaluation: A

Tewari and Goldberg also calculated $K=2.02\cdot10^{-9}$ and $\Delta_rH^\circ=14.7\,\mathrm{kJ\,mol^{-1}}$ at $T=298.15$ K and $I=0$ for the reference reaction: L-iditol(aq)+$\mathrm{NAD^-}$(aq)=L-sorbose(aq)+$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

D-mannitol(aq)+NAD(aq)=D-fructose(aq)+NADH(aq)

T/K	pH	K'
298.15	7.0	0.045

Reference: 89SCH/GIF
Method: spectrophotometry
Buffer: potassium phosphate ($0.10\,\mathrm{mol\,dm^{-3}}$)
pH: 7.0
Evaluation: C

Schneider and Giffhorn reported $K'c(\mathrm{H^+})/c^\circ = 4.5\cdot 10^{-9}$ at pH=7.0. The apparent equilibrium constant given here was calculated from this result.

D-sorbitol(aq)+NAD(aq)=**D**-fructose(aq)+NADH(aq)

T/K	pH	K'
298.15	7.0	0.0058

Reference: 89SCH/GIF
Method: spectrophotometry
Buffer: potassium phosphate ($0.10\,\mathrm{mol\,dm^{-3}}$)
pH: 7.0
Evaluation: C

Schneider and Giffhorn reported $K'c(\mathrm{H^+})/c^\circ = 5.8\cdot 10^{-10}$ at pH=7.0. The apparent equilibrium constant given here was calculated from this result.

D-sorbitol(aq)+NAD(aq)=**D**-fructose(aq)+NADH(aq)

		I_m	
T/K	pH	mol·kg^{-1}	K'
298.15	7.63	0.197	0.094

Reference: 96TEW/GOL
Method: HPLC and spectrophotometry
Buffer: phosphate
pH: 7.63
Evaluation: A

Tewari and Goldberg also calculated $K = 9.0\cdot 10^{-10}$ and $\Delta_r H^\circ = 21.3\,\mathrm{kJ\,mol^{-1}}$ at $T = 298.15\,\mathrm{K}$ and $I = 0$ for the reference reaction: **D**-sorbitol(aq)+$\mathrm{NAD^-}$(aq)=**D**-fructose(aq) +$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

D-sorbitol(aq)+NAD(aq)=**D**-fructose(aq)+NADH(aq)

		I_m	$\Delta_r H$(cal)
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
298.15	7.55	0.217	−17.1

Reference: 96TEW/GOL
Method: calorimetry
Buffer: phosphate
pH: 7.55
Evaluation: A

Tewari and Goldberg also calculated $K = 9.0\cdot 10^{-10}$ and $\Delta_r H^\circ = 21.3\,\mathrm{kJ\,mol^{-1}}$ at $T = 298.15\,\mathrm{K}$ and $I = 0$ for the reference reaction: **D**-sorbitol(aq)+$\mathrm{NAD^-}$(aq)=**D**-fructose(aq) +$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

xylitol(aq)+NAD(aq)=**D**-xylulose(aq)+NADH(aq)

		I_m	
T/K	pH	mol·kg^{-1}	K'
298.15	7.51	0.189	0.00122

Reference: 96TEW/GOL
Method: HPLC and spectrophotometry
Buffer: phosphate
pH: 7.51
Evaluation: A

Tewari and Goldberg also calculated $K = 1.53\cdot 10^{-11}$ and $\Delta_r H^\circ = 39.4\,\mathrm{kJ\,mol^{-1}}$ at $T = 298.15\,\mathrm{K}$ and $I = 0$ for the reference reaction: xylitol(aq)+$\mathrm{NAD^-}$(aq)=**D**-xylulose(aq) +$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

xylitol(aq)+NAD(aq)=**D**-xylulose(aq)+NADH(aq)

		I_m	$\Delta_r H$(cal)
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
298.15	7.43	0.218	−35.2

Reference: 96TEW/GOL
Method: calorimetry
Buffer: phosphate
pH: 7.43
Evaluation: A

Tewari and Goldberg also calculated $K = 1.53\cdot 10^{-11}$ and $\Delta_r H^\circ = 39.4\,\mathrm{kJ\,mol^{-1}}$ at $T = 298.15\,\mathrm{K}$ and $I = 0$ for the reference reaction: xylitol(aq)+$\mathrm{NAD^-}$(aq)=**D**-xylulose(aq) +$\mathrm{NADH^{2-}}$(aq)+$\mathrm{H^+}$(aq).

4.3. Enzyme: L-lactate dehydrogenase (EC 1.1.1.27)

(*S*)-lactate(aq)+NAD(aq)=pyruvate(aq)+NADH(aq)

		$\Delta_r H$(cal)
T/K	pH	kJ·mol^{-1}
298.15	7.5	41.8

Reference: 76SCH/KRI
Method: calorimetry
Buffer: phosphate ($0.07\,\mathrm{mol\,dm^{-3}}$)
pH: 7.0
Evaluation: C

4.4. Enzyme: ribitol 2-dehydrogenase (EC 1.1.1.56)

ribitol(aq)+NAD(aq)=D-ribulose(aq)+NADH(aq)

T/K	pH	K'
298.15	7.0	0.0033

Reference: 92KAH/SCH
Method: spectrophotometry
Buffer: phosphate ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: C

Kahle and Schneider report $K'c(\mathrm{H^+})/c^\circ = 3.3\cdot 10^{-10}$ at pH =7.0. The apparent equilibrium constant given here was calculated from this result.

4.5. Enzyme: mannitol 2-dehydrogenase (EC 1.1.1.67)

D-mannitol(aq)+NADP(aq)=D-fructose(aq)+NADPH(aq)

T/K	pH	K'
310.15	7.5	0.0917

Reference: 94NOE/COL
Method: HPLC and spectrophotometry
Buffer: Tris ($0.020\ \mathrm{mol\ dm^{-3}}$) + HCl
pH: 7.5
Evaluation: B

4.6. Enzyme: carnitine 3-dehydrogenase (EC 1.1.1.108)

D-carnitine(aq)+NAD(aq)=3-dehydrocarnitine(aq) +NADH(aq)

T/K	pH	K'
295.15	8.0	0.00022
295.15	9.0	0.0022

Reference: 97HAN/KLE
Method: spectrophotometry and HPLC
Buffer: Tris ($0.05\ \mathrm{mol\ dm^{-3}}$) + HCl
pH: 8.0–9.0
Evaluation: B

Hanschmann and Kleber report $K'c(\mathrm{H^+})/c^\circ = 2.2\cdot 10^{-12}$ over the pH range 8.0–9.0. The apparent equilibrium constants given here were calculated from this result.

4.7. Enzyme: 15-hydroxyprostaglandin dehydrogenase (NAD^+) (EC 1.1.1.141)

prostaglandin E_2(aq)+NAD(aq)=15-oxo-prostaglandin E_2(aq)+NADH(aq)

T/K	pH	K'
298.15	7.0	$1.77\cdot 10^{2}$
298.15	8.0	$1.77\cdot 10^{3}$

Reference: 75SCH/GRE
Method: spectrophotometry
Buffer: Tris ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0–8.0
Evaluation: C

This approximate result was calculated from kinetic data. Schlegel and Greep reported that $K'c(\mathrm{H^+})/c^\circ = 1.77\cdot 10^{-5}$ but did not report the pH(s). We have assumed that the pH was in the range 7.0–8.0.

4.8. Enzyme: glucose oxidase (EC 1.1.3.4)

β-D-glucose(aq)+O_2(aq)=D-glucono-1,5-lactone(aq) +H_2O_2(aq)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	6.86	−125

Reference: 93BOH/HUT
Method: calorimetry
Buffer: phosphate ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 6.86
Evaluation: A

The same result was obtained by Hüttl *et al.* [93HUT/BOH].

β-D-glucose(aq)+$\frac{1}{2}O_2$(aq)=D-glucono-1,5-lactone(aq) +H_2O(l)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
300.15	7.0	−207.1

Reference: 76SCH/KRI
Method: calorimetry
Buffer: phosphate ($0.066\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: C

Catalase (EC 1.11.1.6) was also present.

β-D-glucose(aq)+$\frac{1}{2}O_2$(aq)=D-glucono-1,5-lactone(aq) +H_2O(l)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	6.86	−223

Reference: 93HUT/BOH
Method: calorimetry
Buffer: phosphate
pH: 6.86
Evaluation: B

Catalase (EC 1.11.1.6) was also present.

4.9. Enzyme: cholesterol oxidase (EC 1.1.3.6)

cholesterol(aq)+O_2(aq)=cholest-4-en-3-one(aq)+H_2O_2(l)

		$\Delta_r H$(cal)
T/K	pH	kJ·mol^{-1}
303.15	7.0	−114

Reference: 78MCG/BRO
Method: calorimetry
Buffer: phosphate (0.067 mol dm^{-3})
pH: 7.0
Evaluation: B

cholesterol(aq)+$\frac{1}{2}O_2$(aq)=cholest-4-en-3-one(aq)+H_2O(l)

		$\Delta_r H$(cal)
T/K	pH	kJ·mol^{-1}
303.15	7.0	−214

Reference: 78MCG/BRO
Method: calorimetry
Buffer: phosphate (0.067 mol dm^{-3})
pH: 7.0
Evaluation: B

Catalase (EC 1.11.1.6) was also present.

cholesterol(aq)+$\frac{1}{2}O_2$(aq)=cholest-4-en-3-one(aq)+H_2O(l)

		$\Delta_r H$(cal)
T/K	pH	kJ·mol^{-1}
303.15	6.9	−153.4

Reference: 82REH/YOU
Method: calorimetry
Buffer: phosphate
pH: 6.9
Evaluation: B

Catalase (EC 1.11.1.6) was also present.

4.10. Enzyme: prephenate dehydrogenase (EC 1.3.1.12)

prephenate(aq)+NAD(aq)+H_2O(l)=4-hydroxyphenylpyruvate(aq)+NADH(aq)+carbon dioxide(aq)

		I_m	$\Delta_r H$(cal)
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
298.15	6.98	0.32	−79.0

Reference: 99KIS/HOL
Method: calorimetry
Buffer: phosphate
pH: 6.98
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T=298.15\ \text{K}, I=0) = -74\ \text{kJ mol}^{-1}$ for the reference reaction: prephenate^{2-}(aq)+NAD^-(aq)+H_2O(l)=4-hydroxyphenylpyruvate$^-$(aq)+$NADH^{2-}$(aq)+HCO_3^-(aq)+H^+(aq).

4.11. Enzyme: dihydrooratate dehydrogenase (1.3.99.11)

(S)-dihydroorotate(aq)+ oxonic acid(aq) = orotate(aq)+ dihydroxonic acid(aq)

T/K	pH	K'
298.15	7.0	0.040

Reference: 98THO/JOR
Method: spectrophotometry
Buffer: sodium phosphate (0.1 mol dm^{-3})
pH: 7.0
Evaluation: B

4.12. Enzyme: glycine dehydrogenase (decarboxylating) (EC 1.4.4.2)

glycine(aq)+α-lipoate(aq)=(*S*)-aminomethyldihydro-α-lipoate(aq)+carbon dioxide(aq)

T/K	pH	K'
311.15	6.39	0.0310
311.15	6.39	0.0222
311.15	6.62	0.0221
311.15	6.80	0.0301
311.15	6.83	0.0465
311.15	6.99	0.0511
311.15	6.99	0.0328
311.15	6.99	0.0344
311.15	7.01	0.0302
311.15	7.03	0.0140
311.15	7.04	0.0121
311.15	7.17	0.0240
311.15	7.18	0.0197
311.15	7.20	0.0229
311.15	7.79	0.008 29

Reference: 85LIE
Method: spectrophotometry and enzymatic assay
Buffer: phosphate
pH: 6.39–7.79
Evaluation: A

The ionic strength was 0.25 mol dm^{-3}.

4.13. Enzyme: glutathione reductase (NADPH) (EC 1.6.4.2)

2 reduced glutathione(aq)+NAD(aq)=oxidized glutathione(aq)+NADH(aq)

T/K	pH	K'_c
313.15	7.0	0.001

Reference: 64ROS/RAP
Method: spectrophotometry
Buffer: phosphate ($0.125\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: C

Few details are given in this study.

2 reduced glutathione(aq)+NADP(aq)=oxidized glutathione(aq)+NADPH(aq)

T/K	pH	K'_c
298.15	7.00	0.0053
298.15	7.82	0.0373
298.15	8.00	0.049
298.15	8.47	0.138

Reference: 75GOR/ESF
Method: spectrophotometry
Buffer: phosphate ($0.1\ \mathrm{mol\ dm^{-3}}$) and Tris ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0–8.47
Evaluation: A

4.14. Enzyme: urate oxidase (EC 1.7.3.3)

urate(aq)+$\frac{1}{2}O_2$(aq)+2 H_2O(l)=allantoin(aq)+carbon dioxide(aq)

		$\Delta_r H$(cal)
T/K	pH	kJ·mol^{-1}
303.15	9.0	−149.6

Reference: 77REH/JAN
Method: calorimetry
Buffer: Tris ($0.02\ \mathrm{mol\ dm^{-3}}$)+HCl
pH: 9.0
Evaluation: B

Catalase (EC 1.11.1.6) was also present.

4.15. Enzyme: dihydrolipoamide dehydrogenase (EC 1.8.1.4)

dihydro-α-lipoate(aq)+NAD(aq)=α-lipoate(aq)+NADH(aq)

		$c(MgCl_2)$	I_c	
T/K	pH	mol·dm^{-3}	mol·dm^{-3}	K'
298.15	6.87	0	0.25	0.138
298.15	6.89	0	0.25	0.130
298.15	7.08	0	0.25	0.267
298.15	7.09	0	0.25	0.270
298.15	7.09	0	0.25	0.294
298.15	7.12	0	0.25	0.329
298.15	7.35	0	0.25	0.445
298.15	7.41	0	0.25	0.579
298.15	7.37	0	0.10	0.360
298.15	6.60	0	0.12	0.100
298.15	7.19	0	0.35	0.287
298.15	7.21	0	0.35	0.349
298.15	7.18	0	0.35	0.338
298.15	7.11	0	0.60	0.253
298.15	7.14	0	0.60	0.334
298.15	7.03	0	1.10	0.160
298.15	7.05	0	1.10	0.264
311.15	6.27	0	0.25	0.051
311.15	6.41	0	0.25	0.067
311.15	6.72	0	0.25	0.088
311.15	6.73	0	0.25	0.141
311.15	6.75	0	0.25	0.141
311.15	6.79	0	0.25	0.138
311.15	6.82	0	0.25	0.129
311.15	6.84	0	0.25	0.150
311.15	6.91	0	0.25	0.139
311.15	6.91	0	0.25	0.143
311.15	6.94	0	0.25	0.187
311.15	6.94	0	0.25	0.197
311.15	6.98	0	0.25	0.260
311.15	6.98	0	0.25	0.271
311.15	7.05	0	0.25	0.271
311.15	7.05	0.010	0.25	0.116
311.15	7.06	0	0.25	0.266
311.15	7.07	0	0.25	0.340
311.15	7.07	0.010	0.25	0.105
311.15	7.09	0	0.25	0.328
311.15	7.16	0.010	0.25	0.257
311.15	7.17	0	0.25	0.268
311.15	7.23	0	0.25	0.351
311.15	7.24	0	0.25	0.321
311.15	7.25	0	0.25	0.309
311.15	7.30	0	0.25	0.385
311.15	7.35	0	0.25	0.498
311.15	7.58	0	0.25	0.634
311.15	7.60	0	0.25	0.620
311.15	8.09	0	0.25	2.37
311.15	8.12	0	0.25	2.04
311.15	8.27	0	0.25	3.55
311.15	8.29	0	0.25	2.75
311.15	8.39	0	0.25	3.55
311.15	8.49	0	0.25	3.86
311.15	8.49	0	0.25	6.55

Reference: 85LIE
Method: spectrophotometry
Buffer: potassium phosphate ($0.050\ \mathrm{mol\ dm^{-3}}$) or sodium pyrophosphate ($0.030\ \mathrm{mol\ dm^{-3}}$)
pH: 6.27–8.49
Evaluation: A

Liegel calculated $K(T=311.15\ \text{K},\ I_c \approx 0.25\ \text{mol dm}^{-3}) = 2.08 \cdot 10^{-8}$ and $K(T=298.15\ \text{K},\ I_c \approx 0.25\ \text{mol dm}^{-3}) = 2.13 \cdot 10^{-8}$ for the reference reaction: dihydro-α-lipoate$^-$(aq)+NAD$^-$(aq) = α-lipoate$^-$(aq) + NADH^{2-}(aq) +H$^+$(aq). Liegel also stated that the earlier measurements of Sanadi *et al.* [59SAN/LAN] may not have been at equilibrium.

4.16. Enzyme: catalase (EC 1.11.1.6)

$H_2O_2(aq) = \frac{1}{2}O_2(aq) + H_2O(l)$

T/K	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	−100.4

Reference: 72NEL/KIE
Method: calorimetry
Buffer: none
pH: not reported
Evaluation: A

Also see entries given under glucose oxidase (EC 1.1.3.4) and cholesterol oxidase (EC 1.1.3.6).

$H_2O_2(aq) = \frac{1}{2}O_2(aq) + H_2O(l)$

T/K	pH	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	7.0	−83.7

Reference: 95LIA/WAN
Method: calorimetry
Buffer: phosphate (0.067 mol dm^{-3})
pH: 7.0
Evaluation: C

Also see entries given under glucose oxidase (EC 1.1.3.4) and cholesterol oxidase (EC 1.1.3.6).

$H_{22}(aq) = \frac{1}{2}O_2(aq) + H_2O(l)$

T/K	pH	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	7.0	−88.88

Reference: 97LIA/WU
Method: calorimetry
Buffer: phosphate
pH: 7.0
Evaluation: B

4.17. Enzyme: peroxidase (EC 1.11.1.7)

$H_2O_2(aq)$ +reduced thiocyanate(aq)=oxidized thiocyanate(aq)+$H_2O(l)$

T/K	pH	K'_c
310.15	7.0	$3.8 \cdot 10^3$

Reference: 86PRU/TEN
Method: enzymatic assay and chemical analysis
Buffer: phosphate
pH: 7.0
Evaluation: B

The value of K'_c given here was calculated from the concentrations given in Pruitt *et al.*'s Table I. Pruitt *et al.* also calculated $K'_c(T=310.15\ \text{K}) = 3.7 \cdot 10^3$ for the reference reaction: $H_2O_2(aq) + SCN^-(aq) = OSCN^-(aq) + H_2O(l)$.

4.18. Enzyme: alkanal monooxygenase (FMN-linked) (EC 1.14.14.3)

dodecanal(aq)+reduced riboflavin 5′-phosphate(aq)+O_2(aq) =dodecanoic acid(aq)+oxidized riboflavin 5′-phosphate(aq) +H_2O(l)

T/K	pH	$\Delta_r H$(cal) kJ·mol^{-1}
280.15	7.0	−350
298.15	7.0	−308

Reference: 75MAN/LAN
Method: calorimetry
Buffer: potassium phosphate (0.15 mol dm^{-3})
pH: 7.0
Evaluation: C

Light is emitted by this reaction.

4.19. Enzyme: camphor 5-monooxygenase (EC 1.14.15.1)

(+)-camphor(aq)+NADH(aq)+O_2(aq)=(+)-5-*exo*-hydroxycamphor(aq)+NAD(aq)+H_2O(l)

T/K	pH	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	7.4	−405.8

Reference: 69PET/MCK
Method: calorimetry
Buffer: Tris+HCl
pH: 7.4
Evaluation: B

4.20. Enzyme: glycine hydroxymethyltransferase (EC 2.1.2.1)

5,10-methylenetetrahydrofolate(aq)+glycine(aq)+H_2O(l) =5,6,7,8-tetrahydrofolate(aq)+L-serine(aq)

T/K	pH	K'
303.15	7.3	0.125
308.15	7.5	0.083

Reference: 77SCH/TAT
Method: spectrophotometry and radioactivity

Buffer: potassium phosphate
pH: 7.3–7.5
Evaluation: A

5,10-methylenetetrahydrofolate(aq)+glycine(aq)+H_2O(l) = 5,6,7,8-tetrahydrofolate(aq)+**L**-serine(aq)

T/K	pH	K'
310.15	7.4	0.067

Reference: 93BES/REB
Method: radioactivity
Buffer: KH_2PO_4 (0.020 mol dm^{-3})
pH: 7.4
Evaluation: B

tetraglutamyl-5,10-methylenetetrahydrofolate(aq) +glycine(aq)+H_2O(l)=tetraglutamyl-5,6,7,8-tetrahydrofolate(aq)+**L**-serine(aq)

T/K	pH	K'
310.15	7.4	0.063

Reference: 93BES/REB
Method: radioactivity
Buffer: KH_2PO_4 (0.020 mol dm^{-3})
pH: 7.4
Evaluation: B

4.21. Enzyme: serine *O*-acetyltransferase (EC 2.3.1.30)

acetyl-CoA(aq)+**L**-serine(aq)=CoA(aq)+*O*-acetyl-**L**-serine(aq)

T/K	pH	K'
298.15	6.0	15

Reference: 94LEU/COO
Method: spectrophotometry
Buffer: Mes (0.1 mol dm^{-3})
pH: 6.0
Evaluation: A

4.22. Enzyme: sucrose synthase (EC 2.4.1.13)

UDPglucose(aq)+**D**-fructose(aq)=UDP(aq)+sucrose(aq)

T/K	pH	Buffer	K'
303.15	7.0	Hepes	6.7
303.15	9.4	Ches	250

Reference: 97DEJ/ROC
Method: enzymatic assay and spectrophotometry
Buffer: {Hepes (0.050 mol dm^{-3})+NaOH} and {Ches (0.050 mol dm^{-3})+NaOH}
pH: 7.0–9.4
Cofactor(s): $MgCl_2$
Evaluation: B

4.23. Enzyme: cyclomaltodextrin glucanotransferase (EC 2.4.1.19)

G_u(aq)=cyclomaltohexaose(aq)+$G_{(u-6)}$(aq)

T/K	pH	K'_c
311.15	6.5	0.0134

Reference: 50PAZ
Method: HPLC
Buffer: NaCN+$NaC_2H_3O_2$
pH: 6.5
Evaluation: A

G_1 represents **D**-glucose and G_n (n is a positive integer) represents a linear maltodextrin; u is an integer $\geqslant 7$. The result given here is based upon Tewari and Goldberg's recalculation [97TEW/GOL] of Pazur's original data.

G_u(aq)=cyclomaltohexaose(aq)+$G_{(u-6)}$(aq)

T/K	pH	K'_m
329.6	5.55	0.0229

Reference: 97TEW/GOL
Method: HPLC
Buffer: phosphate
pH: 5.55
Evaluation: A

G_1 represents **D**-glucose and G_n (n is a positive integer) represents a linear maltodextrin; u is an integer $\geqslant 7$.

G_v(aq)=cyclomaltoheptaose(aq)+$G_{(v-7)}$(aq)

T/K	pH	K'_c
311.15	6.5	0.0334

Reference: 50PAZ
Method: HPLC
Buffer: NaCN+$NaC_2H_3O_2$
pH: 6.5
Evaluation: A

G_1 represents **D**-glucose and G_n (n is a positive integer) represents a linear maltodextrin; v is an integer $\geqslant 8$. The result given here is based upon Tewari and Goldberg's recalculation [97TEW/GOL] of Pazur's original data.

G_v(aq)=cyclomaltoheptaose(aq)+$G_{(v-7)}$(aq)

T/K	pH	K'_m
329.6	5.55	0.0390

Reference: 97TEW/GOL
Method: HPLC
Buffer: phosphate
pH: 5.55
Evaluation: A

G_1 represents D-glucose and G_n (n is a positive integer) represents a linear maltodextrin; v is an integer $\geqslant 8$.

$G_w(aq) = \text{cyclomaltooctaose}(aq) + G_{(w-8)}(aq)$

T/K	pH	K'_c
311.15	6.5	0.0194

Reference: 50PAZ
Method: HPLC
Buffer: $NaCN + NaC_2H_3O_2$
pH: 6.5
Evaluation: A

G_1 represents D-glucose and G_n (n is a positive integer) represents a linear maltodextrin; w is an integer $\geqslant 9$. The result given here is based upon Tewari and Goldberg's recalculation [97TEW/GOL] of Pazur's original data.

$G_w(aq) = \text{cyclomaltooctaose}(aq) + G_{(w-8)}(aq)$

T/K	pH	K'_m
329.6	5.55	0.0103

Reference: 97TEW/GOL
Method: HPLC
Buffer: phosphate
pH: 5.55
Evaluation: A

G_1 represents D-glucose and G_n (n is a positive integer) represents a linear maltodextrin; w is an integer $\geqslant 9$.

$\text{cyclomaltohexaose}(aq) + 6\ H_2O(l) = 6\ \text{D-glucose}(aq)$

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	4.58	−50.85

Reference: 97TEW/GOL
Method: calorimetry
Buffer: KH_2PO_4 (0.10 mol kg^{-1})
pH: 4.58
Evaluation: A

Glucan1,4-α-glucosidase (EC 3.2.1.3) was also present.

4.24. Enzyme: cellobiose phosphorylase (EC 2.4.1.20)

$\text{cellobiose}(aq) + \text{orthophosphate}(aq) = \text{D-glucose}(aq) + \alpha\text{-D-glucose 1-phosphate}(aq)$

T/K	pH	K'
310.15	7.0	0.23

Reference: 61ALE
Method: enzymatic assay
Buffer: barbital (0.0075 mol dm^{-3}) + acetate
pH: 7.0
Evaluation: B

4.25. Enzyme: UDP-*N*-acetylglucosamine 1-carboxyvinyltransferase (EC 2.5.1.7)

(Z)-phospho*enol*butyrate(aq) + UDP-*N*-acetyl-D-glucosamine(aq) = orthophosphate(aq) + *(Z)-enol*butyryl-UDP-*N*-acetylglucosamine(aq)

T/K	pH	K'
298.15	8.0	65

Reference: 95LEE/WAL
Method: HPLC
Buffer: Tris (0.050 mol dm^{-3})
pH: 8.0
Evaluation: C

This is an approximate result.

4.26. Enzyme: glutathione transferase (EC 2.5.1.18)

reduced glutathione(aq) + ethyl-(*E*)-2-octenoate(aq) = glutathionyl-ethyl-(*E*)-2-octenoate(aq)

T/K	pH	K'_c
298.15	7.4	435

Reference: 94CHI/KIR
Method: HPLC
Buffer: phosphate (0.066 mol dm^{-3})
pH: 7.4
Evaluation: B

reduced glutathione(aq) + methyl-(*E*)-2-octenoate(aq) = glutathionyl-methyl-(*E*)-2-octenoate(aq)

T/K	pH	K'_c
298.15	7.4	212

Reference: 94CHI/KIR
Method: HPLC
Buffer: phosphate (0.066 mol dm^{-3})
pH: 7.4
Evaluation: B

reduced glutathione(aq) + (*E*)-3-nonen-2-one(aq) = glutathionyl-(*E*)-3-nonen-2-one(aq)

T/K	pH	K'_c
298.15	7.4	$2.6 \cdot 10^3$

Reference: 94CHI/KIR
Method: HPLC

Buffer: phosphate ($0.066\ \mathrm{mol\ dm^{-3}}$)
pH: 7.4
Evaluation: B

reduced glutathione(aq) + (*E*) - 2 -octenal(aq) = glutathionyl-(*E*)- 2-octenal(aq)

T/K	pH	K'_c
298.15	7.4	$7.1 \cdot 10^3$

Reference: 94CHI/KIR
Method: HPLC
Buffer: phosphate ($0.066\ \mathrm{mol\ dm^{-3}}$)
pH: 7.4
Evaluation: B

reduced glutathione(aq) + (*E*) - 4 - phenyl - 3-buten-2-one(aq) =4-(glutathionyl)-4-phenyl-2-butanone(aq)

T/K	pH	K'_c
298.15	8.0	640

Reference: 95CHE/ARM
Method: spectrophotometry
Buffer: Tris ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 8.0
Evaluation: B

4-(glutathionyl)-4-phenyl-2-butanone) is an equimolar mixture of the (4*R*) and (4*S*) stereoisomers. The sums of the concentrations of the two stereoisomers was used in the calculation of the value of K'_c which was obtained from the analysis of kinetic data.

4.27. Enzyme: aspartate transaminase (EC 2.6.1.1)

L-aspartate(aq)+2-oxoglutarate(aq)=oxaloacetate(aq) +L-glutamate(aq)

T/K	pH	I_m / $\mathrm{mol \cdot kg^{-1}}$	K'
283.15	7.00	0.163	0.133
288.15	7.12	0.167	0.144
292.65	7.07	0.165	0.133
298.15	7.13	0.164	0.143
303.15	6.94	0.163	0.145

Reference: 98KIS/TEW2
Method: HPLC
Buffer: phosphate
pH: 6.94–7.13
Evaluation: A

Kishore *et al.* calculated $K = 0.143$, $\Delta_r H° = 1.9\ \mathrm{kJ\ mol^{-1}}$, and $\Delta_r S° = -10\ \mathrm{J\ K^{-1}\ mol^{-1}}$ at $T = 298.15$ K and $I = 0$ for the reference reaction: L-aspartate$^-$(aq)+2-oxoglutarate^{2-}(aq)=oxaloacetate^{2-}(aq)+L-glutamate$^-$(aq).

4.28. Enzyme: alanine transaminase (EC 2.6.1.2)

L-alanine(aq)+2-oxoglutarate(aq)=pyruvate(aq) +L-glutamate(aq)

T/K	pH	I_c / $\mathrm{mol \cdot dm^{-3}}$	K'
311.15	7.0	0.25	0.68

Reference: 68BRO
Method: spectrophotometry
Buffer: phosphate ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: A

Also see Brosnan *et al.* [70BRO/KRE].

L-alanine(aq)+2-oxoglutarate(aq)=pyruvate(aq) +L-glutamate(aq)

T/K	pH	I_c / $\mathrm{mol \cdot dm^{-3}}$	K'
311.15	7.0	0.25	0.68

Reference: 70BRO/KRE
Method: spectrophotometry
Buffer: phosphate ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: A

Also see Brosnan [68BRO].

L-alanine(aq)+2-oxoglutarate(aq)=pyruvate(aq) +L-glutamate(aq)

T/K	pH	I_m / $\mathrm{mol \cdot kg^{-1}}$	K'
298.15	6.60	0.15	0.72
298.15	7.23	0.19	0.78

Reference: 98TEW/KIS
Method: HPLC
Buffer: phosphate
pH: 6.60–7.23
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K = 1.36$ and $\Delta_r H° = 5.9\ \mathrm{kJ\ mol^{-1}}$ at $T = 298.15$ K and $I = 0$ for the reference reaction: L-alanine(aq)+2-oxoglutarate^{2-}(aq)=pyruvate$^-$(aq) +L-glutamate$^-$(aq).

L-alanine(aq)+2-oxoglutarate(aq)=pyruvate(aq) +L-glutamate(aq)

T/K	pH	I_m / $\mathrm{mol \cdot kg^{-1}}$	$\Delta_r H$(cal) / $\mathrm{kJ \cdot mol^{-1}}$
298.15	7.37	0.34	5.2

Reference: 98TEW/KIS
Method: calorimetry
Buffer: phosphate
pH: 7.37
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K=1.36$ and $\Delta_r H°=5.9$ kJ mol^{-1} at $T=298.15$ K and $I=0$ for the reference reaction: L-alanine(aq)+2-oxoglutarate^{2-}(aq)=pyruvate^{-}(aq)+L-glutamate^{-}(aq).

4.29. Enzyme: tyrosine transaminase (EC 2.6.1.5)

L-phenylalanine(aq)+2-oxoglutarate(aq)=phenylpyruvate(aq)+L-glutamate(aq)

T/K	pH	I_m / mol·kg^{-1}	K'
298.15	7.46	0.32	1.024
298.15	7.57	0.33	1.069

Reference: 98TEW/KIS
Method: HPLC
Buffer: phosphate
pH: 7.46–7.57
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K=2.14$ and $\Delta_r H°=9.5$ kJ mol^{-1} at $T=298.15$ K and $I=0$ for the reference reaction: L-phenylalanine(aq)+2-oxoglutarate^{2-}(aq) =phenylpyruvate^{-}(aq)+L-glutamate^{-}(aq).

L-phenylalanine(aq)+2-oxoglutarate(aq)=phenylpyruvate(aq)+L-glutamate(aq)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.30	0.34	8.3

Reference: 98TEW/KIS
Method: calorimetry
Buffer: phosphate
pH: 7.30
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K=2.14$ and $\Delta_r H°=9.5$ kJ mol^{-1} at $T=298.15$ K and $I=0$ for the reference reaction: L-phenylalanine(aq)+2-oxoglutarate^{2-}(aq) =phenylpyruvate^{-}(aq)+L-glutamate^{-}(aq).

L-tyrosine(aq)+2-oxoglutarate(aq)=4-hydroxyphenylpyruvate(aq)+L-glutamate(aq)

T/K	pH	I_m / mol·kg^{-1}	K'
298.15	7.45	0.32	0.880
298.15	7.74	0.33	0.876

Reference: 98TEW/KIS
Method: HPLC
Buffer: phosphate
pH: 7.45–7.74
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K=1.82$ and $\Delta_r H°=10.1$ kJ mol^{-1} at $T=298.15$ K and $I=0$ for the reference reaction: L-tyrosine(aq)+2-oxoglutarate^{2-}(aq)=4-hydroxyphenylpyruvate^{-}(aq)+L-glutamate^{-}(aq).

L-tyrosine(aq)+2-oxoglutarate(aq)=4-hydroxyphenylpyruvate(aq)+L-glutamate(aq)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.64	0.34	8.4

Reference: 98TEW/KIS
Method: calorimetry
Buffer: phosphate
pH: 7.64
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Tewari *et al.* also calculated $K=1.82$ and $\Delta_r H°=10.1$ kJ mol^{-1} at $T=298.15$ K and $I=0$ for the reference reaction: L-tyrosine(aq)+2-oxoglutarate^{2-}(aq)=4-hydroxyphenylpyruvate^{-}(aq)+L-glutamate^{-}(aq).

4.30. Enzyme: branched-chain-amino-acid transaminase (EC 2.6.1.42)

L-leucine(aq)+2-oxoglutarate(aq)=4-methyl-2-oxopentanoate(aq)+L-glutamate(aq)

T/K	pH	K'
310.15	8.6	1.75

Reference: 70JEN/TAY
Method: spectrophotometry
Buffer: Tris
pH: 8.6
Evaluation: C

Few details are given in this study.

4.31. Enzyme: polyamine transaminase (EC 2.6.1.-)

L-alanine(aq)+3-aminopropionaldehyde(aq)=pyruvate(aq)+1,3-diaminopropane(aq)

T/K	pH	K'
303.15	9.0	2.9

Reference: 97YOR/ISH
Method: spectrophotometry

Buffer: Tris ($0.1\ \mathrm{mol\ dm^{-3}}$) + HCl
pH: 9.0
Evaluation: B

4.32. Enzyme: choline kinase (2.7.1.32)

ATP(aq) + choline(aq) = ADP(aq) + *O*-phosphocholine(aq)

T/K	pH	*K′*
303.15	9.5	0.2

Reference: 98KIM/VOE
Method: radioactivity
Buffer: glycine ($0.067\ \mathrm{mol\ dm^{-3}}$) + NaOH
pH: 9.5
Cofactor(s): $MgSO_4$ ($0.010\ \mathrm{mol\ dm^{-3}}$)
Evaluation: B

4.33. Enzyme: phosphoglycerate kinase (EC 2.7.2.3)

ATP(aq) + 3-phospho-**D**-glycerate(aq) = ADP(aq) + 3-phospho-**D**-glyceroyl phosphate(aq)

T/K	pH	Cosolvent	*K′*
277.15	7.5	none	0.000 15
277.15	7.5	ethylene glycol, 40%	0.000 08

Reference: 95SCH/TRA
Method: radioactivity
Buffer: triethanolamine ($0.020\ \mathrm{mol\ dm^{-3}}$)
pH: 7.5
Cofactor(s): Mg^{2+} ($0.001\ \mathrm{mol\ dm^{-3}}$)
Evaluation: C

Schmidt *et al.* did not state what the ''percent'' of ethylene glycol was, i.e., volume percent, mass percent, or mole percent.

4.34. Enzyme: creatine kinase (EC 2.7.3.2)

phosphocreatine(aq) + cyclocreatine(aq) = creatine(aq) + phosphocyclocreatine(aq)

T/K	pH	*K′*
296.15	7.0	34.3

Reference: 95WIS/KUS
Method: NMR and HPLC
Buffer: Mops ($0.1\ \mathrm{mol\ dm^{-3}}$) + Tris ($0.070\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: B

phosphocreatine(aq) + β-guanidinopropionate(aq) = creatine(aq) + β-phosphoguanidinopropionate(aq)

T/K	pH	*K′*
298.15	7.06	3.06

Reference: 86MEY/BRO
Method: enzymatic assay
Buffer: Pipes ($0.050\ \mathrm{mol\ dm^{-3}}$)
pH: 7.06
Cofactor(s): $MgCl_2$ ($0.010\ \mathrm{mol\ dm^{-3}}$)
Evaluation: B

The temperature was assumed to be 298.15 K.

phosphocreatine(aq) + β-guanidinopropionate(aq) = creatine(aq) + β-phosphoguanidinopropionate(aq)

T/K	pH	*K′*
296.15	7.0	3.1

Reference: 95WIS/KUS
Method: NMR and HPLC
Buffer: Mops ($0.1\ \mathrm{mol\ dm^{-3}}$) + Tris ($0.070\ \mathrm{mol\ dm^{-3}}$)
pH: 7.0
Evaluation: B

4.35. Enzyme: arginine kinase (2.7.3.3)

ATP(aq) + **L**-arginine(aq) = ADP(aq) + N^{ω}-phospho-**L**-arginine(aq)

T/K	pH	*K′*
298.15	7.2	17.5

Reference: 97CHA
Method: spectrophotometry
Buffer: imidazole ($0.1\ \mathrm{mol\ dm^{-3}}$)
pH: 7.2
Cofactor(s): $MgCl_2$ ($0.005\ \mathrm{mol\ dm^{-3}}$)
Evaluation: B

4.36. Enzyme: taurocyamine kinase (EC 2.7.3.4)

ATP(aq) + taurocyamine(aq) = ADP(aq) + N^{ω}-phosphotaurocyamine(aq)

T/K	pH	*K′*
285.15	7.3	$1 \cdot 10^9$

Reference: 95KAM/JUR
Method: enzymatic analysis
Buffer: Tris ($0.1\ \mathrm{mol\ dm^{-3}}$) + HCl
pH: 7.3
Cofactor(s): magnesium acetate ($0.10\ \mathrm{mol\ dm^{-3}}$)
Evaluation: C

The reported value of *K′* is exceptionally large and it is not clear how it could have been measured.

4.37. Enzyme: adenylate kinase (EC 2.7.4.3)

2 ADP(aq) = AMP(aq) + ATP(aq)

T/K	pH	*K′*
285.15	7.3	0.36

Reference: 95KAM/JUR

Method: enzymatic analysis
Buffer: Tris ($0.1\ mol\ dm^{-3}$) + HCl
pH: 7.3
Cofactor(s): magnesium acetate ($0.060\ mol\ dm^{-3}$)
Evaluation: C

4.38. Enzyme: guanylate kinase (EC 2.7.4.8)

ATP(aq) + GMP(aq) = ADP(aq) + GDP(aq)

T/K	pH	$c(MgCl_2)$ / mol·dm^{-3}	K'
298.15	7.5	0.0056	1.5
298.15	7.5	0.013	3.1
298.15	7.5	0.020	5.2
298.15	7.5	0.045	5.3
298.15	7.7	0.0050	2.1

Reference: 96LI/ZHA
Method: NMR and radioactivity
Buffer: Tris+HCl
pH: 7.5–7.7
Cofactor(s): Mg^{2+}
Evaluation: A

Results obtained from kinetic experiments were also found to be consistent with the values of K' obtained from the equilibrium measurements.

4.39. Enzyme: UTP-glucose-1-phosphate uridylyltransferase (EC 2.7.7.9)

UTP(aq) + α-D-glucose 1-phosphate(aq) = pyrophosphate(aq) + UDPglucose(aq)

T/K	pH	K'
303.15	8.5	0.26

Reference: 69TSU/FUK
Method: fluorimetry
Buffer: Tris ($0.050\ mol\ dm^{-3}$)
pH: 8.5
Cofactor(s): $MgCl_2$
Evaluation: B

4.40. Enzyme: [glutamate-ammonia-ligase] adenylyltransferase (EC 2.7.7.42)

ATP(aq) + [L-glutamate:ammonia ligase (ADP-forming)](aq) = pyrophosphate(aq) + adenylyl-[L-glutamate:ammonia ligase (ADP-forming)](aq)

T/K	pH	Buffer	$c(MgSO_4)$ / mol·dm^{-3}	pMg	K'
278.5	7.4	Tris	0.010	2.0	57.4
283.2	7.4	Tris	0.010	2.0	28.8
288.0	7.4	Tris	0.010	2.0	21.8
298.2	7.4	Tris	0.010	2.0	19.6
303.0	7.4	Tris	0.010	2.0	17.8
303.15	6.73	Tris	0.010	not given	5.0
303.15	7.0	imidazole	0.010	not given	12.9
303.15	7.03	Tris	0.010	not given	12.8
303.15	7.4	Tris	0.0027	not given	4.2
303.15	7.4	Tris	0.005	not given	12.3
303.15	7.4	Tris	0.010	not given	23.6
303.15	7.4	Tris	0.020	not given	38.2
303.15	7.57	Tris	0.010	not given	48.2
309.5	7.4	Tris	not given	2.0	18.5

Reference: 71WOH
Method: enzymatic assay
Buffer: {Tris ($0.10\ mol\ dm^{-3}$) + HCl} and {imidazole ($0.1\ mol\ dm^{-3}$) + HCl}
pH: 6.73–7.57
Evaluation: A

The apparent equilibrium constants given here were obtained from Wohlhueter's Table 3 and Figs. 2, 3, and 4. We calculate $\Delta_r H'^\circ(\langle T\rangle = 291\ K,\ pH = 7.4,\ pMg = 2.0) \approx -28\ kJ\ mol^{-1}$ from the temperature dependency of the apparent equilibrium constant.

4.41. Enzyme: UDPhexose synthase (EC 2.7.7.-)

UDPglucose (aq) + imidazole (aq) = α-D-glucose 1-phosphate(aq) + UMPimidazole(aq)

T/K	pH	Buffer	K'
300.15	7.0	MOPS	0.00064
300.15	8.5	bicine	0.022

Reference: 96ARA/RUZ
Method: HPLC and fluorimetry
Buffer: Mops ($0.095\ mol\cdot dm^{-3}$) and Bicine ($0.095\ mol\cdot dm^{-3}$)
pH: 7.0–8.5
Evaluation: A

UDPhexose synthase is a mutant of UDPglucose-hexose-1-phosphate uridylyltransferase (EC 2.7.7.12).

4.42. Enzyme: triacylglycerol lipase (EC 3.1.1.3)

1-dodecanoic acid(sln) + 1-dodecanol(sln) = dodecyldodecanoate(sln) + H_2O(sln)

T/K	Solvent	K
298.15	hexane	39.6
298.15	heptane	35.3
298.15	cyclohexane	23.3
298.15	2,2,4-trimethylpentane	27.2
298.15	toluene	17.9

Reference: 98TEW
Method: HPLC, GC, and Karl Fischer analysis
Evaluation: A

This reaction was studied in five organic solvents. Tewari also calculated $K_m(T=298.15\ \text{K},\ I=0)=2.9\cdot10^6$ for the reaction: 1-dodecanol(aq) + 1-dodecanoic acid(aq) =dodecyldodecanoate(aq)+H_2O(l).

1-dodecanoic acid(sln)+(-)-menthol(sln)=(-)-menthyldodecanoate(sln)+H_2O(sln)

T/K	Solvent	K
298.15	*n*-hexane	6.5
298.15	*n*-heptane	21.7
298.15	cyclohexane	23.7
298.15	2,2,4-trimethylpentane	16.2
298.15	toluene	12.0
298.15	acetonitrile	3.23
298.15	2-methyl-2-butanol	5.8

Reference: 99TEW/SCH
Method: GC and Karl Fischer
Evaluation: A

This reaction was studied in seven organic solvents. Tewari *et al.* also determined saturation molalities and (hexane +H_2O) partition coefficients for (-)-menthol, 1-dodecanoic acid, and (-)menthyldodecanoate. By using a thermodynamic cycle calculation they calculated $K_m(T=298.15\ \text{K},\ I=0)=1.9\cdot10^5$ for the reference reaction: (-)-menthol(aq) +1-dodecanoic acid(aq)=(-)-menthyl dodecanoate(aq) +H_2O(l).

tributyrylglycerol(sln) + (*R*)-2-decanol(sln) = (*R*)-2-decylbutyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.015
303.15	benzene	0.018
303.15	dioxane	0.025
303.15	acetonitrile	0.028

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

tributyrylglycerol(sln)+(*R*)-2-dodecanol(sln)=(*R*)-2-dodecylbutyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.017
303.15	benzene	0.017
303.15	dioxane	0.020
303.15	acetonitrile	0.025

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

tributyrylglycerol(sln)+(*R*)-2-heptanol(sln)=(*R*)-2-heptylbutyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.026
303.15	benzene	0.028
303.15	dioxane	0.037
303.15	acetonitrile	0.038

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

tributyrylglycerol(sln)+(*R*)-2-nonanol(sln)=(*R*)-2-nonylbutyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.020
303.15	benzene	0.020
303.15	dioxane	0.027
303.15	acetonitrile	0.029

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

tributyrylglycerol(sln)+(*R*)-2-octanol(sln)=(*R*)-2-octylbutyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.022
303.15	benzene	0.024
303.15	dioxane	0.028
303.15	acetonitrile	0.029

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

tributyrylglycerol(sln)+(*R*)-2-undecanol(sln)=(*R*)-2-undecyl butyrate(sln)+glycerol-1,2-dibutyrate(sln)

T/K	Solvent	K
303.15	hexane	0.017
303.15	benzene	0.017
303.15	dioxane	0.022
303.15	acetonitrile	0.026

Reference: 96HIR/MAY
Method: HPLC and GC
Evaluation: B

The results obtained with hexane and benzene are the averages of the results obtained using two different lipases.

4.43. Enzyme: tannase (EC 3.1.1.20)

3,4,5-trihydroxybenzoic acid propyl ester(aq)+H_2O(l)=3,4,5-trihydroxybenzoate(aq)+1-propanol(aq)

T/K	pH	I_m / mol·kg^{-1}	K'_m
293.15	5.33	0.080	126
293.15	5.31	0.080	119
298.15	4.99	0.052	57.3
298.15	5.00	0.052	61.1
298.15	5.32	0.080	122.1
298.15	5.36	0.082	117
298.15	5.38	0.084	147
298.15	5.39	0.085	128
298.15	5.91	0.109	435
298.15	5.91	0.111	448
298.15	6.56	0.135	2409
298.15	6.56	0.135	2820
303.15	5.37	0.082	121
303.15	5.35	0.081	123
308.15	5.32	0.081	114
308.15	5.34	0.081	124

Reference: 96TEW/SCH
Method: HPLC
Buffer: sodium acetate
pH: 4.99–6.56
Evaluation: A

Tewari *et al.* also calculated $K_m = 4.37 \cdot 10^{-4}$ and $\Delta_r H° = -4.6$ kJ mol^{-1} at $T = 298.15$ K and $I = 0$ for the reference reaction: 3,4,5-trihydroxybenzoic acid propyl ester(aq)+H_2O(l)=3,4,5-trihydroxybenzoate$^-$(aq)+1-propanol(aq)+H^+(aq).

3,4,5-trihydroxybenzoic acid propyl ester(aq)+H_2O(l)=3,4,5-trihydroxybenzoate(aq)+1-propanol(aq)

T/K	pH	Buffer	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	5.61	phosphate	0.092	−8.33
298.15	6.18	Mes	0.027	−19.8

Reference: 96TEW/SCH
Method: HPLC
Buffer: phosphate and Mes
pH: 5.61–6.18
Evaluation: A

Tewari *et al.* also calculated $K_m = 4.37 \cdot 10^{-10}$ and $\Delta_r H° = -4.6$ kJ mol^{-1} at $T = 298.15$ K and $I = 0$ for the reference reaction: 3,4,5-trihydroxybenzoic acid propyl ester(aq)+H_2O(l)=3,4,5-trihydroxybenzoate$^-$(aq)+1-propanol(aq)+H^+(aq).

3,4,5-trihydroxybenzoic acid propyl ester(sln)+H_2O(sln)=3,4,5-trihydroxybenzoate(sln)+1-propanol(sln)

T/K	K
293.25	0.0128
298.25	0.0130
303.15	0.0112
308.15	0.0098

Reference: 96TEW/SCH
Method: HPLC, GC, and Karl Fischer analysis
Evaluation: A

Toluene was the solvent used in this study. Tewari *et al.* also calculated $\Delta_r H°(\langle T \rangle = 301\ \text{K}) = -15.4$ kJ mol^{-1} from the temperature dependence of the equilibrium constant.

4.44. Enzyme: pancreatic ribonuclease (3.1.27.5)

guanosine 2′:3′-(cyclic)phosphate(aq)+H_2O(l)=guanosine 3′-monophosphate(aq)

T/K	pH	K'
308.15	6.0	≈13

Reference: 98LOV/LAU
Method: mass spectrometry
Buffer: imidazole (0.0125 mol dm^{-3})
pH: 6.0
Evaluation: B

Ribonuclease T1 (EC 3.1.27.3) was also used in this study. The value of K' given here was calculated from the average value $K'c°/c(H_2O) = 0.38$ given by Loverix *et al.* in their Table 1. The solution used in this study contained methanol

(40% by volume). This result is based on the analysis of kinetic data.

guanosine 2′ : 3′ - (cyclic) phosphate (aq) + methanol (aq) = guanosine 3′-methylphosphate(aq)

T/K	pH	K'_c
308.15	6.0	≈0.95

Reference: 98LOV/LAU
Method: mass spectrometry
Buffer: imidazole ($0.0125 mol\,dm^{-3}$)
pH: 6.0
Evaluation: B

Ribonuclease T1 (EC 3.1.27.3) was also used. This result is based on the analysis of kinetic data.

uridine 2′: 3′ - (cyclic)phosphate(aq) + H_2O(l) = uridine 3′-monophosphate(aq)

T/K	pH	K'
298.15	5.0	440

Reference: 69ROS/HAM
Method: chromatography and radioactivity
Buffer: Tris ($0.1 mol\,dm^{-3}$) + acetate
pH: 5.0
Evaluation: B

4.45. Enzyme: α-amylase (EC 3.2.1.1)

cyclomaltoheptaose(aq) + 7 H_2O(l) = 7 **D**-glucose(aq)

T/K	pH	$\Delta_r H$(cal) / $kJ \cdot mol^{-1}$
298.15	5.14	−48.79

Reference: 97TEW/GOL
Method: calorimetry
Buffer: KH_2PO_4 ($0.10 mol\,kg^{-1}$)
pH: 5.14
Evaluation: A

Glucan 1,4-α-glucosidase (EC 3.2.1.3) was also present.

cyclomaltooctaose(aq) + 8 H_2O(l) = 8 **D**-glucose(aq)

T/K	pH	$\Delta_r H$(cal) / $kJ \cdot mol^{-1}$
298.15	5.15	−52.29

Reference: 97TEW/GOL
Method: calorimetry
Buffer: KH_2PO_4 ($0.10 mol\,kg^{-1}$)
pH: 5.15
Evaluation: A

Glucan 1,4-α-glucosidase (EC 3.2.1.3) was also present.

4.46. Enzyme: glucan 1,4-α-glucosidase (EC 3.2.1.3)

6-*O*-α-**D**-galactopyranosyl-**D**-galactopyranose(aq) + H_2O(l) = 2 **D**-galactose(aq)

T/K	pH	K'_c
318.15	4.5	$\approx 1.04 \cdot 10^3$

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05 mol\,dm^{-3}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table V. In this study, the position of equilibrium was not approached from both directions. Pestlin *et al.* also report additional data for reactions where the exact identity of the products is uncertain.

4-*O*-α-**D**-glucopyranosyl-**D**-fructofuranose(aq) + H_2O(l) = **D**-glucose(aq) + **D**-fructose(aq)

T/K	pH	K'_c
318.15	4.5	372

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05 mol\,dm^{-3}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table IV.

3-*O*-α-**D**-glucopyranosyl-lyxopyranose(aq) + H_2O(l) = **D**-glucose(aq) + lyxose(aq)

T/K	pH	K'_c
318.15	4.5	330

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05 mol\,dm^{-3}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table VII.

α-isomaltose(aq) + H_2O(l) = 2 **D**-glucose(aq)

T/K	pH	K'_c
318.15	4.5	81

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here is the average of the results calculated from the concentrations given in Pestlin *et al.*'s Tables III to X.

β-isomaltose(aq)+H_2O(l)=2 **D**-glucose(aq)

T/K	pH	K'_c
318.15	4.5	65

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here is the average of the results calculated from the concentrations given in Pestlin *et al.*'s Tables III to X.

1-*O*-α-**D**-mannopyranosyl-**D**-mannofuranose(aq)+H_2O(l) =2 **D**-mannose(aq)

T/K	pH	K'_c
318.15	4.5	$1.26\cdot 10^3$

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table VIII.

6-*O*-α-**D**-mannopyranose-**D**-mannopyranose(aq)+H_2O(l) =2 **D**-mannose(aq)

T/K	pH	K'_c
318.15	4.5	≈ 420

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table VIII.

α-**D**-melibiose(aq)+H_2O(l)=**D**-galactose(aq) +**D**-glucose(aq)

T/K	pH	K'_c
318.15	4.5	53

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table V.

β-**D**-melibiose(aq)+H_2O(l)=**D**-galactose(aq) +**D**-glucose(aq)

T/K	pH	K'_c
318.15	4.5	40

Reference: 97PES/PRI
Method: GC+MS
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.5
Evaluation: B

The result given here was calculated from the concentrations given in Pestlin *et al.*'s Table V.

4.47. Enzyme: β-galactosidase (EC 3.2.1.23)

*allo*lactose(aq)+H_2O(l)=**D**-galactose(aq)+**D**-glucose(aq)

T/K	pH	K'_c
310.15	7.0	45

Reference: 92ELL/SRI
Method: HPLC
Buffer: Tes ($0.030\ \mathrm{mol\ dm^{-3}}$)+NaOH
pH: 7.0
Cofactor(s): $MgCl_2$($0.001\ \mathrm{mol\ dm^{-3}}$)
Evaluation: A

lactose(aq)+H_2O(l)=**D**-galactose(aq)+**D**-glucose(aq)

T/K	pH	K'_c
310.15	7.0	152

Reference: 92ELL/SRI
Method: HPLC
Buffer: Tes ($0.030\ \mathrm{mol\ dm^{-3}}$)+NaOH
pH: 7.0
Cofactor(s): $MgCl_2$($0.001\ \mathrm{mol\ dm^{-3}}$)
Evaluation: A

lactulose(aq)+H_2O(l)=**D**-galactose(aq)+**D**-fructose(aq)

T/K	pH	K'_c
310.15	7.0	40

Reference: 92ELL/SRI
Method: HPLC

Buffer: Tes ($0.030\ \mathrm{mol\ dm^{-3}}$)+NaOH
pH: 7.0
Cofactor(s): $MgCl_2$($0.001\ \mathrm{mol\ dm^{-3}}$)
Evaluation: A

4.48. Enzyme: β-fructofuranosidase (EC: 3.2.1.26)

sucrose(aq)+H_2O(l)=D-glucose(aq)+D-fructose(aq)

		$\Delta_r H$(cal)
T/K	pH	$\mathrm{kJ\cdot mol^{-1}}$
298.15	4.6	−15.5

Reference: 99HUT/OEH
Method: calorimetry
Buffer: acetate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 4.6
Cofactor(s): Cd^{2+}, Zn^{2+}, As^{3+}, As^{+5}, and Ag^{+}
Evaluation: B

The result given here is the average of the results obtained from experiments in which several different heavy metal ion cofactors were present. This result is in agreement with the result obtained from experiments in which no heavy metal ions were present.

4.49. Enzyme: chymotrypsin (EC 3.4.21.1)

N-acetyl-L-phenylalanine ethyl ester(aq)+H_2O(l)
=*N*-acetyl-L-phenylalanine(aq)+ethanol(aq)

		I_m	
T/K	pH	$\mathrm{mol\cdot kg^{-1}}$	K'_m
288.15	6.09	0.11	$3.55\cdot10^3$
288.15	6.29	0.11	$7.98\cdot10^3$
293.15	6.17	0.11	$2.27\cdot10^3$
293.15	6.39	0.13	$4.28\cdot10^3$
298.15	6.19	0.12	$4.04\cdot10^3$
298.15	6.44	0.13	$5.29\cdot10^3$
308.15	5.98	0.11	$1.63\cdot10^3$
308.15	6.23	0.12	$1.99\cdot10^3$

Reference: 95TEW/SCH
Method: HPLC and GC
Buffer: phosphate
pH: 5.98–6.44
Evaluation: A

Tewari *et al.* also calculated $K_m=1.7\cdot10^{-3}$ and $\Delta_r H°=-3.5\ \mathrm{kJ\ mol^{-1}}$ at $T=298.15$ K and $I=0$ for the reference reaction: *N*-acetyl-L-phenylalanine ethyl ester(aq)+H_2O(l) =*N*-acetyl-L-phenylalanine$^-$(aq)+ethanol(aq)+H^+(aq).

N-acetyl-L-phenylalanine ethyl ester(sln)+H_2O(sln)
=*N*-acetyl-L-phenylalanine(sln)+ethanol(sln)

T/K	Solvent	K
283.15	dichloromethane	0.0377
288.15	dichloromethane	0.0437
293.25	dichloromethane	0.0513
298.25	dichloromethane	0.0572
283.15	carbon tetrachloride	0.38
288.15	carbon tetrachloride	0.30
293.25	carbon tetrachloride	0.23
298.25	carbon tetrachloride	0.197
283.15	toluene	0.182
288.15	toluene	0.201
293.25	toluene	0.144
298.25	toluene	0.107

Reference: 95TEW/SCH
Method: HPLC, GC, and Karl Fischer analysis
Evaluation: A

Tewari *et al.* calculated the following values of $\Delta_r H°$ from the temperature dependence of the equilibrium constants: $\Delta_r H°(\langle T\rangle=291\ \mathrm{K})=20\ \mathrm{kJ\ mol^{-1}}$ for the reaction in dichloromethane; $\Delta_r H°(\langle T\rangle=291\ \mathrm{K})=-28\ \mathrm{kJ\ mol^{-1}}$ for the reaction in carbon tetrachloride; and $\Delta_r H°(\langle T\rangle=291\ \mathrm{K})=-26\ \mathrm{kJ\ mol^{-1}}$ for the reaction in toluene.

N-acetyl-L-tryptophan ethyl ester(aq)+H_2O(l)=*N*-acetyl-L-tryptophan(aq)+ethanol(aq)

		I_c	$\Delta_r H$(cal)
T/K	pH	$\mathrm{mol\cdot dm^{-3}}$	$\mathrm{kJ\cdot mol^{-1}}$
298.15	7.5	0.1	−5.9

Reference: 71RAJ/LUM
Method: calorimetry
Buffer: phosphate ($0.05\ \mathrm{mol\ dm^{-3}}$)
pH: 7.5
Evaluation: B

Rajender *et al.* applied buffer protonation and ionization corrections to obtain $\Delta_r H°=3.3\ \mathrm{kJ\ mol^{-1}}$ for the reference reaction: *N*-acetyl-L-tryptophan ethyl ester(aq)+H_2O(l)=*N*-acetyl-L-tryptophan(aq)+ethanol(aq).

N-acetyl-L-tyrosine ethyl ester(aq)+H_2O(l)=*N*-acetyl-L-tyrosine(aq)+ethanol(aq)

		$\Delta_r H$(cal)
T/K	pH	$\mathrm{kJ\ mol^{-1}}$
298.15	7.8	−48.5

Reference: 95LIU/ZEN
Method: calorimetry
Buffer: Tris

pH: 7.8
Evaluation: B

2-propylhippurate(aq) + H_2O(l) = 2-propanol(aq) + hippurate(aq)

T/K	pH	$\Delta_r H$(cal) / kJ mol^{-1}
298.15	7.0	−48.9

Reference: 95LIU/ZEN
Method: calorimetry
Buffer: Tris
pH: 7.0
Evaluation: B

4.50. Enzyme: thermolysin (EC 3.4.24.27)

N-(benzyloxycarbonyl)-L-aspartyl-L-phenylalanine methyl ester(aq) + H_2O(l) = *N*-(benzyloxycarbonyl)-L-aspartic acid(aq) + L-phenylalanine methyl ester(aq)

T/K	pH	K'_c
313.15	6.0	0.79

Reference: 86NAK/KIM
Method: HPLC
Buffer: Mes (0.05 M) + NaOH
pH: 6.0
Cofactor(s): $CaCl_2$ (0.005 mol dm^{-3})
Evaluation: B

Nakanishi *et al.* reported $K'_c \cdot c(H_2O) = 1/70$. The apparent equilibrium constant given here was calculated from this result.

N-(benzyloxycarbonyl)-L-aspartyl-L-phenylalanine methyl ester(aq) + H_2O(l) = *N*-(benzyloxycarbonyl)-L-aspartic acid(aq) + L-phenylalanine methyl ester(aq)

T/K	pH	K'_c
313.15	≈6.5	0.67

Reference: 84OYA/IRI
Method: HPLC
Buffer: No specific buffering system was used. The pH was adjusted with NaOH.
pH: ≈6.5
Evaluation: B

4.51. Enzyme: asparaginase (EC 3.5.1.1)

L-asparagine(aq) + H_2O(l) = L-aspartate(aq) + ammonia(aq)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.03	0.27	−25.63

Reference: 99KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 7.03
Evaluation: A

Kishore *et al.* also calculated $\Delta_r H°(T = 298.15\,\text{K}, I = 0) = -26.2\,\text{kJ mol}^{-1}$ for the reference reaction: L-asparagine$^{\pm}$(aq) + H_2O(l) = L-aspartate^{-}(aq) + NH_4^+(aq).

4.52. Enzyme: glutaminase (EC 3.5.1.2)

L-glutamine(aq) + H_2O(l) = L-glutamate(aq) + ammonia(aq)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	5.14	0.11	−24.39

Reference: 99KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 5.14
Evaluation: A

Kishore *et al.* also calculated $\Delta_r H°(T = 298.15\,\text{K}, I = 0) = -25.2\,\text{kJ mol}^{-1}$ for the reference reaction: L-glutamine$^{\pm}$(aq) + H_2O(l) = L-glutamate^{-}(aq) + NH_4^+(aq).

4.53. Enzyme: urease (EC 3.5.1.5)

ammonium carbamate(aq) + H_2O(l) = 2 ammonia(aq) + carbon dioxide(aq)

T/K	pH	Buffer	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	6.3	Mes	−18.2
298.15	6.86	phosphate	−32.7
298.15	7.0	Hepes	−14.7
298.15	8.0	Tris	8.7

Reference: 95HUT/BOH
Method: calorimetry
Buffer: phosphate, Tris, Mes, and Hepes
pH: 6.86–8.0
Evaluation: B

urea(aq) + 2 H_2O(l) = 2 ammonia(aq) + carbon dioxide(aq)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
300.15	7.0	−7.1
300.15	8.0	−8.4

Reference: 76SCH/KRI

Method: calorimetry
Buffer: Tris ($0.05\ mol\ dm^{-3}$)
pH: 7.0
Evaluation: C

urea(aq)+2 H_2O(l)=2 ammonia(aq)+carbon dioxide(aq)

T/K	pH	Buffer	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	6.0	phosphate	−52.9
298.15	6.5	phosphate	−61.0
298.15	6.86	phosphate	−58.6
298.15	7.6	phosphate	−50.9
298.15	7.0	Tris	−16.4
298.15	6.3	Mes	−46.0
298.15	7.0	Hepes	−42.0

Reference: 95HUT/BOH
Buffer: phosphate, Tris, Mes, and Hepes
pH: 6.0–7.6
Evaluation: B

urea(aq)+2 H_2O(l)=2 ammonia(aq)+carbon dioxide(aq)

T/K	pH	I_c / mol·dm^{-3}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.0	0.07	−59.6

Reference: 95JUS/KOT
Method: calorimetry
Buffer: phosphate ($0.022\ mol\ dm^{-3}$)
pH: 7.0
Evaluation: C

4.54. Enzyme: penicillin amidase (EC 3.5.1.11)

amoxicillin(aq)+H_2O(l)=6-aminopenicillanic acid(aq)
+D-4-hydroxyphenylglycine(aq)

T/K	pH	K'_c
298.15	5.0	2.86
298.15	5.6	7.04
298.15	6.0	17.7

Reference: 98DIE/STR
Method: HPLC
Buffer: K_2HPO_4 ($0.1\ mol\ dm^{-3}$)+NaOH or HCl
pH: 5.0–6.0
Evaluation: A

The values of K'_c given here were obtained from Diender *et al.*'s Fig. 3. Diender *et al.* also report values of the pKs and solubilities of the reactants and products.

4.55. Enzyme: aminoacylase (EC 3.5.1.14)

N-acetyl-L-methionine(aq)+H_2O(l)=L-methionine(aq)
+acetate(aq)

T/K	pH	K'_c
310.15	7.0	2.7

Reference: 95BIS/KRA
pH: 7.0
Evaluation: C

Few details are given in this study.

4.56. Enzyme: D-(-)-phenylglycyl-β-lactamide amidohydrolase (EC 3.5.1.-)

ampicillin(aq)+H_2O(l)=6-aminopenicillanic acid(aq)
+D(-)-α-aminophenylacetic acid(aq)

T/K	pH	K'_c
298.15	5.50	0.18

Reference: 93BLI/MAR
pH: 5.50
Evaluation: B

cephalexin(aq) + H_2O(l) = 7-aminodeacetoxycephalosporanic acid(aq)+D(-)-α-aminophenylacetic acid(aq)

T/K	pH	K'_c
298.15	5.25	0.12

Reference: 93BLI/MAR
pH: 5.25
Evaluation: B

4.57. Enzyme: arginase (EC 3.5.3.1)

L-arginine(aq)+H_2O(l)=L-ornithine(aq)+urea(aq)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	9.4	−17.8

Reference: 95LIA/WAN2
Method: calorimetry
Buffer: diethylbarbiturate
pH: 9.4
Evaluation: B

This same result was also given later by Liang *et al.* [96LIA/WAN].

L-arginine(aq)+$H_2O(l)$=L-ornithine(aq)+urea(aq)

T/K	pH	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	9.5	−18.1

Reference: 95LIU/ZEN
Method: calorimetry
Buffer: glycine+NaOH
pH: 9.5
Evaluation: B

4.58. Enzyme: *N*-acetylneuraminate lyase (EC 4.1.3.3)

N-acetylneuraminate(aq) = *N*-acetyl-D-mannosamine(aq) +pyruvate(aq)

T/K	pH	K'_c
310.15	7.2	0.096

Reference: 62BRU/JOU
Method: radioactivity and spectrophotometry
Buffer: phosphate (0.1 mol dm^{-3})
pH: 7.2
Evaluation: A

This result supersedes the earlier result of Comb and Roseman [62COM/ROS].

N-acetylneuraminate(aq) = *N*-acetyl-D-mannosamine(aq) +pyruvate(aq)

T/K	pH	K'_c
310.15	7.7	0.08

Reference: 84UCH/TSU
Method: spectrophotometry
Buffer: phosphate (0.050 mol dm^{-3})
pH: 7.7
Evaluation: B

The apparent equilibrium constant given here was calculated from the data given in Uchida *et al.*'s Fig. 7.

N-acetylneuraminate(aq) = *N*-acetyl-D-mannosamine(aq) +pyruvate(aq)

T/K	pH	K'_c
283.15	7.5	0.0120
298.15	7.5	0.0348

Reference: 91KRA/GYG
Method: HPLC
Buffer: none
pH: 7.5
Evaluation: A

Also see Kragel's thesis [92KRA].

N-acetylneuraminate(aq)=*N*-acetyl-D-mannosamine(aq) +pyruvate(aq)

T/K	pH	K'_c
278.3	7.5	0.00898
287.9	7.5	0.0165
298.15	7.5	0.0340
309.8	7.5	0.0641
309.8	7.5	0.0758
317.7	7.5	0.127

Reference: 92KRA
Method: HPLC
Buffer: none
pH: 7.5
Evaluation: A

The apparent equilibrium constants given here were obtained from Kragel's Fig. 3.2-1. Kragel also calculated $\Delta_r H'°(\langle T\rangle = 298\,\mathrm{K}, p\mathrm{H}=7.5) = 47.8\,\mathrm{kJ\,mol^{-1}}$ for this biochemical reaction from the temperature dependency of the apparent equilibrium constant. Also see Kragl *et al.* [91KRA/GYG].

2-oxo-3-deoxy-D-glycero-D-galacto-nonopyranulosonate(aq) =D-mannose(aq)+pyruvate(aq)

T/K	pH	K'_c
298.15	7.5	0.0524

Reference: 97SAL/GOD
Method: HPLC
Buffer: none
pH: 7.5
Evaluation: B

N-glycolylneuraminate(aq) = *N*-glycolyl-D-mannosamine(aq)+pyruvate(aq)

T/K	pH	K'_c
310.15	7.2	0.090

Reference: 62BRU/JOU
Method: radioactivity and spectrophotometry
Buffer: phosphate (0.1 mol dm^{-3})
pH: 7.2
Evaluation: A

4.59. Enzyme: chorismate lyase (EC 4.1.3.-)

chorismate(aq)=4-hydroxybenzoate(aq)+pyruvate(aq)

T/K	pH	I_m mol·kg^{-1}	$\Delta_r H$(cal) kJ·mol^{-1}
298.15	6.98	0.38	−144.1

Reference: 98TEW/CHE

Method: calorimetry
Buffer: phosphate
pH: 6.98
Evaluation: A

Tewari *et al.* also calculated $\Delta_r H°(T=298.15\ \text{K}, I=0) = -144\ \text{kJ mol}^{-1}$ for the reference reaction: chorismate^{2-}(aq)=pyruvate^{-}(aq)+4-hydroxybenzoate^{-}(aq).

4.60. Enzyme: cyclohexa-1,5-diene-1-carboxyl-coenzyme A hydratase (4.2.1.-)

cyclohexa-1,5-diene-1-carboxyl-CoA(aq)+$H_2O(l)$ =6-hydroxycyclohex-1-ene-carboxyl-CoA(aq)

T/K	pH	K'
310.15	7.4	1.0

Reference: 98LAE/EIS
Method: HPLC+radioactivity
Buffer: potassium phosphate ($0.1\ \text{mol dm}^{-3}$)
pH: 7.4
Evaluation: B

4.61. Enzyme: tryptophan synthase (EC 4.2.1.20)

D-glyceraldehyde 3-phosphate(aq)+indole(aq)=1-(indol-3-yl)glycerol 3-phosphate(aq)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.5	−33.8

Reference: 85WIE/HIN
Method: calorimetry and spectrophotometry
Buffer: sodium diphosphate ($0.1\ \text{mol dm}^{-3}$)
pH: 7.5
Evaluation: A

Wiesinger and Hinz reported $\Delta_r H(\text{cal}) = -54.0\ \text{kJ mol}^{-1}$ for this biochemical reaction. However, the reported value included a correction for the hydration of the aldehyde form of **D**-glyceraldehyde 3-phosphate to its diol form. In the absence of these corrections, the value of $\Delta_r H(\text{cal})$ for this reaction is $-33.8\ \text{kJ mol}^{-1}$ (H. Wiesinger, personal communication cited by Kishore *et al.* [98KIS/TEW]). This entry supersedes the entry made in Goldberg and Tewari's [95GOL/TEW] earlier review.

indole(aq)+**D**-glyceraldehyde 3-phosphate(aq)=1-(indol-3-yl)glycerol 3-phosphate(aq)

T/K	pH	I_m / mol·kg^{-1}	K'_m
298.15	7.54	0.37	$1.2\cdot10^{4}$

Reference: 98KIS/TEW
Method: HPLC
Buffer: phosphate
pH: 7.54
Evaluation: A

Kishore *et al.* calculated $K_m(T=298.15\ \text{K}, I=0) = 1.2\cdot10^{-4}$ for the reference reaction: indole^0(aq)+**D**-glyceraldehyde 3-phosphate^{2-}(aq)=1-(indol-3-yl)glycerol 3-phosphate^{2-}(aq).

indole(aq)+**D**-glyceraldehyde 3-phosphate(aq)=1-(indol-3-yl)glycerol 3-phosphate(aq)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.26	0.37	−46.9

Reference: 98KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 7.26
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T=298.15\ \text{K}, I=0) = -46.9\ \text{kJ mol}^{-1}$ for the reference reaction: indole^0(aq)+**D**-glyceraldehyde 3-phosphate^{2-}(aq) =1-(indol-3-yl)glycerol 3-phosphate^{2-}(aq).

indole(aq)+**L**-serine(aq)=**L**-tryptophan(aq)+H_2O(l)

T/K	pH	I_m / mol·kg^{-1}	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.01	0.32	−74.5

Reference: 98KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 7.01
Cofactor(s): pyridoxal 5-phosphate
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T=298.15\ \text{K}, I=0) = -74.3\ \text{kJ mol}^{-1}$ for the reference reaction: indole^0(aq)+**L**-serine$^{\pm}$(aq)=**L**-tryptophan$^{\pm}$(aq)+H_2O(l).

1-(indol-3-yl)glycerol 3-phosphate(aq)+**L**-serine(aq)=**L**-tryptophan(aq)+**D**-glyceraldehyde 3-phosphate(aq)+H_2O(l)

T/K	pH	$\Delta_r H$(cal) / kJ·mol^{-1}
298.15	7.5	−34

Reference: 85WIE/HIN
Method: calorimetry and spectrophotometry
Buffer: sodium diphosphate ($0.1\ \text{mol dm}^{-3}$)
pH: 7.5
Evaluation: A

Wiesinger and Hinz reported $\Delta_r H(\text{cal}) = -13.4\ \text{kJ mol}^{-1}$ for this biochemical reaction. However, the reported value included a correction for the hydration of the aldehyde form of **D**-glyceraldehyde 3-phosphate to its diol form. In the absence of these corrections, the value of $\Delta_r H(\text{cal})$ for this reaction is $-34\ \text{kJ mol}^{-1}$ (H. Wiesinger, personal communication cited in Kishore *et al.* [98KIS/TEW]). This entry supersedes the entry made in Goldberg and Tewari's [95GOL/TEW] earlier review.

1-(indol-3-yl)glycerol 3-phosphate(aq) + **L**-serine(aq) = **L**-tryptophan(aq) + **D**-glyceraldehyde 3-phosphate(aq) + H_2O(l)

		I_m	$\Delta_r H(\text{cal})$
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
298.15	7.57	0.36	−27.8

Reference: 98KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 7.57
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T = 298.15\ \text{K}, I = 0) = -27.1\ \text{kJ mol}^{-1}$ for the reference reaction: **L**-serine$^{\pm}$(aq) + 1-(indol-3-yl)glycerol 3-phosphate^{2-}(aq) = **L**-tryptophan$^{\pm}$(aq) + **D**-glyceraldehyde 3-phosphate^{2-}(aq) + H_2O(l).

L-serine(aq) = pyruvate(aq) + ammonia(aq)

		I_m	$\Delta_r H(\text{cal})$
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
308.15	6.90	0.39	−12.1

Reference: 98KIS/TEW
Method: calorimetry
Buffer: phosphate
pH: 6.90
Cofactor(s): pyridoxal 5-phosphate and CsCl
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T = 298.15\ \text{K}, I = 0) = -12.2\ \text{kJ mol}^{-1}$ for the reference reaction: **L**-serine$^{\pm}$(aq) = pyruvate^{-}(aq) + NH_4^+(aq).

4.62. Enzyme: prephenate dehydratase (EC 4.2.1.51)

prephenate(aq) = phenylpyruvate(aq) + carbon dioxide(aq)

		I_m	$\Delta_r H(\text{cal})$
T/K	pH	mol·kg^{-1}	kJ·mol^{-1}
298.15	7.17	0.35	−127.0

Reference: 99KIS/HOL
Method: calorimetry
Buffer: phosphate
pH: 7.17
Evaluation: A

Kishore *et al.* calculated $\Delta_r H°(T = 298.15\ \text{K}, I = 0) = -126\ \text{kJ mol}^{-1}$ for the reference reaction: prephenate^{2-}(aq) = phenylpyruvate^{-}(aq) + HCO_3^-(aq).

4.63. Enzyme: 4-aminobenzoate synthase (EC 4.-)

chorismate(aq) + ammonia(aq) = 4-amino-4-deoxychorismate(aq) + H_2O(l)

T/K	pH	K'_c
310.15	8.6	6.1

Reference: 91AND/KAT
Method: HPLC
Buffer: Tris (0.050 mol dm^{-3})
pH: 8.6
Cofactor(s): $MgCl_2$ (0.010 mol dm^{-3})
Evaluation: B

This reaction was catalyzed by the PabB subunit of 4-aminobenzoate synthase.

4.64. Enzyme: 2-arylpropionyl-coenzyme A epimerase (EC 5.1.2.-)

(*S*)-2-(4-isobutylphenyl)propionyl-CoA(aq) = (*R*)-2-(4-isobutylphenyl)propionyl-CoA(aq)

T/K	pH	K'_c
303.15	7.0	1.5

Reference: 93SHI/CHE
Method: HPLC
Buffer: phosphate (0.10 mol dm^{-3})
pH: 7.0
Evaluation: C

4.65. Enzyme: UDPglucose 4-epimerase (EC 5.1.3.2)

UDPglucose(aq) = UDPgalactose(aq)

T/K	pH	K'
298.15	8.7	≈0.33

Reference: 60MAX/ROB
Method: spectrophotometry
Buffer: glycine (0.1 mol dm^{-3})
pH: 8.7
Evaluation: C

UDPglucose(aq)=UDPgalactose(aq)

T/K	pH	K'
298.15	8.7	0.30

Reference: 70TSA/HOL
Method: spectrophotometry
Buffer: glycine (0.1 mol dm^{-3})+NaOH
pH: 8.7
Evaluation: A

UDPglucose(aq)=UDPgalactose(aq)

T/K	pH	K'
298.15	8.7	0.29

Reference: 80FUK/OBO
Method: spectrophotometry
Buffer: glycine (0.1 mol dm^{-3})+NaOH
pH: 8.7
Evaluation: B

UDPglucose(aq)=UDPgalactose(aq)

T/K	pH	K'
298.15	8.5	0.29

Reference: 96PRO/GRO
Method: spectrophotometry
Buffer: Tris (0.020 mol dm^{-3})+HCl
pH: 8.5
Cofactor(s): $MgCl_2$ (0.001 mol dm^{-3})
Evaluation: C

4.66. Enzyme: *N*-acylglucosamine 2-epimerase (EC 5.1.3.8)

N-acetyl-**D**-glucosamine(aq)=*N*-acetyl-**D**-mannosamine(aq)

T/K	pH	K'
298.15	7.5	0.201

Reference: 92KRA
Method: HPLC
Buffer: none
pH: 7.5
Evaluation: A

4.67. Enzyme: xylose isomerase (EC 5.3.1.5)

D-glucose(aq)=**D**-fructose(aq)

T/K	pH	K'
333.15	7.0	0.98
338.15	7.0	1.03
343.15	7.0	1.14
348.15	7.0	1.22
353.15	7.0	1.39

Reference: 97CON/DEL
Method: HPLC
Buffer: Tris (0.05 mol dm^{-3})
pH: 7.0
Cofactor(s): $MgSO_4$
Evaluation: C

We calculate $\Delta_r H'°(\langle T\rangle = 343.15$ K, pH=7.0)=16.9 kJ mol^{-1} from the temperature dependency of the apparent equilibrium constant.

4.68. Enzyme: glucose-6-phosphate Isomerase (EC 5.3.1.9)

D-glucose 6-phosphate(aq)=**D**-fructose 6-phosphate(aq)

T/K	pH	buffer	K'
310.15	7.0	Imidazole	0.33
310.15	8.0	Tris	0.30

Reference: 97STA/SUA
Method: spectrophotometry
Buffer: Imidazole (0.025 mol dm^{-3}) and Tris (0.025 mol dm^{-3})
pH: 7.0–8.0
Cofactor(s): $MgCl_2$ (0.005 mol dm^{-3})
Evaluation: A

4.69. Enzyme: phosphoglucomutase (EC 5.4.2.2)

α-**D**-glucose 1-phosphate(aq)=α-**D**-glucose 6-phosphate(aq)

T/K	pH	K'
298.15	7.0	3.7

Reference: 96OES/SCH
Method: enzymatic assay and spectrophotometry
Buffer: Tris (0.050 mol dm^{-3})+HCl
pH: 7.0
Cofactor(s): $MgCl_2$ (0.001 mol dm^{-3})
Evaluation: B

Also see data given under phosphomannomutase (EC 5.4.2.8) [95GOL/TEW].

4.70. Enzyme: phosphomannomutase (EC 5.4.2.8)

α-**D**-glucose 1-phosphate(aq)=α-**D**-glucose 6-phosphate(aq)

T/K	pH	K'
298.15	7.0	1.4

Reference: 96OES/SCH
Method: enzymatic assay and spectrophotometry
Buffer: Tris (0.050 mol dm^{-3})+HCl
pH: 7.0
Cofactor(s): $MgCl_2$ (0.001 mol dm^{-3})
Evaluation: B

Also see data given under β-phosphoglucomutase (EC 5.4.2.6) [95GOL/TEW].

D-mannose 1-phosphate(aq) = **D**-mannose 6-phosphate(aq)

T/K	pH	K'
298.15	7.0	1.0

Reference: 96OES/SCH
Method: enzymatic assay and spectrophotometry
Buffer: Tris ($0.050\ \mathrm{mol\,dm^{-3}}$)+HCl
pH: 7.0
Cofactor(s): $MgCl_2$ ($0.001\ \mathrm{mol\,dm^{-3}}$)
Evaluation: B

4.71. Enzyme: chorismate mutase (EC 5.4.99.5)

chorismate(aq) = prephenate(aq)

T/K	pH	buffer	I_m / $\mathrm{mol\cdot kg^{-1}}$	$\Delta_r H$(cal) / $\mathrm{kJ\cdot mol^{-1}}$
298.15	6.93	phosphate	0.18	−55.5
298.15	7.70	Tris	0.071	−55.4

Reference: 97KAS/TEW
Method: calorimetry
Buffer: phosphate and Tris
pH: 6.93
Evaluation: A

Kast *et al.* also calculated $\Delta_r H°(T = 298.15\ \mathrm{K},\ I = 0) = -55.4\ \mathrm{kJ\,mol^{-1}}$ for the reference reaction: chorismate^{2-}(aq) = prephenate^{2-}(aq). This study was complemented by a quantum mechanical calculation of $\Delta_r H°$ for this reference reaction.

4.72. Enzyme: isochorismate synthase (EC 5.4.99.6)

chorismate(aq) = isochorismate(aq)

T/K	pH	K'
298.15	7.5	0.66

Reference: 90LIU/QUI
Method: NMR and spectrophotometry
Buffer: phosphate ($0.050\ \mathrm{mol\,dm^{-3}}$)
pH: 7.5
Cofactor(s): $MgCl_2$ ($0.005\ \mathrm{mol\,dm^{-3}}$)
Evaluation: A

The value $K' = 0.56$ was also obtained from kinetic data and by using the Haldane relationship. The same results are also given in Liu's thesis [90LIU].

chorismate(aq) = isochorismate(aq)

T/K	pH	K'
298.15	8.0	0.55

Reference: 95KOZ/TOM
Method: HPLC
Buffer: $(NH_4)_2SO_4$ ($0.050\ \mathrm{mol\,dm^{-3}}$)
pH: 8.0
Evaluation: C

The temperature was assumed to be 298.15 K.

chorismate(aq) + ammonia(aq) = 2-amino-2-deoxyisochorismate(aq) + H_2O(l)

T/K	pH	K'
298.15	8.0	2.67

Reference: 95KOZ/TOM
Method: HPLC
Buffer: $(NH_4)_2SO_4$ ($0.050\ \mathrm{mol\,dm^{-3}}$)
pH: 8.0
Evaluation: C

The temperature was assumed to be 298.15 K.

5. List of Substances with Chemical Abstract Service (CAS) Registry Numbers with Cross References to Enzyme Commission Numbers

Substance	CAS Registry Number[a]	Enzyme Commission Numbers
acetaldehyde	75-07-0	1.1.1.1
acetate	64-19-7	3.5.1.14
acetyl-coenzyme A	72-89-9	2.31.30
N-acetyl-**D**-glucosamine	7512-17-6	5.1.3.8
N-acetyl-**D**-mannosamine	3615-17-6	4.1.3.3, 5.1.3.8
N-acetyl-**L**-methionine	65-82-7	3.5.1.14
N-acetylneuraminate	131-48-6	4.1.3.3
N-acetyl-**L**-phenylalanine	2018-61-3	3.4.21.1
N-acetyl-**L**-phenylalanine ethyl ester	2361-96-8	3.4.21.1
O-acetyl-**L**-serine	66638-22-0	2.3.1.30
N-acetyl-**L**-tryptophan	1218-34-4	3.4.21.1
N-acetyl-**L**-tryptophan ethyl ester	2382-80-1	3.4.21.1
N-acetyl-**L**-tyrosine	537-55-3	3.4.21.1
N-acetyl-**L**-tyrosine ethyl ester	36546-50-6	3.4.21.1
adenosine 5′-diphosphate	58-64-0	2.7.1.32, 2.7.2.3, 2.7.3.3, 2.7.3.4, 2.7.4.3, 2.7.4.8
adenosine 5′-monophosphate	61-19-8	2.7.4.3
adenosine 5′-triphosphate	56-65-5	2.7.1.32, 2.7.2.3, 2.7.3.3, 2.7.3.4, 2.7.4.3, 2.7.4.8, 2.7.7.42
adenylyl-[**L**-glutamate:ammonia ligase (ADP-forming)]	155039-15-9	2.7.7.42
L-alanine	56-41-7	2.6.1.-, 2.6.1.2
allantoin	97-59-6	1.7.3.3, 1.11.1.6
*allo*lactose	28447-39-4	3.2.1.23
7-aminodeacetoxycephalosporanic acid	22252-43-3	3.5.1.-
4-amino-4-deoxychorismate	97279-79-3	4.-
2-amino-2-deoxyisochorismate	214403-80-2	5.4.99.6
(*S*)-aminomethyldihydro-α-lipoate	214403-81-3	1.4.4.2
6-aminopenicillanic acid	551-16-6	3.5.1.11, 3.5.1.-
D(-)-α-aminophenylacetic acid	875-74-1	3.5.1.-
3-aminopropionaldehyde	352-92-1	2.6.1.-
ammonia	7664-41-7	3.5.1.1, 3.5.1.2, 3.5.1.5, 4.2.1.20, 4.-, 5.4.99.6
ammonium carbamate	1111-78-0	3.5.1.5
amoxicillin	61336-70-7	3.5.1.11
ampicillin	69-53-4	3.5.1.-
D-arabitol	488-82-4	1.1.1.14
L-arginine	74-79-3	2.7.3.3, 3.5.3.1
L-asparagine	70-47-3	3.5.1.1
L-aspartate	56-84-8	2.6.1.1, 3.5.1.1
N-(benzyloxycarbonyl-**L**-aspartic acid	1152-61-0	3.4.24.27
N-(benzyloxycarbonyl)-**L**-aspartyl-**L**-phenylalanine methyl ester	33605-72-0	3.4.24.27
(*Z*)=*enol*butyryl-UDP-*N*-acetylglucosamine	56374-30-2	2.5.1.7
(+)-camphor	464-49-3	1.14.15.1
carbon dioxide	124-38-9	1.3.1.12, 1.4.4.2, 1.7.3.3, 1.11.1.6, 3.5.1.5, 4.2.1.51
D-carnitine	541-14-0	1.1.1.108
cellobiose	528-50-7	2.4.1.20

5. List of Substances with Chemical Abstract Service (CAS) Registry Numbers with Cross References to Enzyme Commission Numbers—Continued

Substance	CAS Registry Number[a]	Enzyme Commission Numbers
cephalexin	15686-71-2	3.51.-
cholest-4-en-3-one	601-57-0	1.1.3.6, 1.11.1.6
cholesterol	57-88-5	1.1.3.6, 1.11.1.6, 4.1.3.-, 4.-, 5.4.99.5, 5.4.99.6
choline	62-49-7	2.7.1.32
chorismate	55508-12-8	4.1.3.-, 4.-, 5.4.99.5, 5.4.99.6
coenzyme A	85-61-0	2.3.1.30
creatine	57-00-1	2.7.3.2
cyclocreatine	35404-50-3	2.7.3.2
cyclohexa-1,5-diene-1-carboxyl-coenzyme A	148471-94-7	4.2.1.-
cyclomaltoheptaose	7585-39-9	2.4.1.19, 3.2.1.1, 3.2.1.3
cyclomaltohexaose	10016-20-3	2.4.1.19, 3.2.1.3
cyclomaltooctaose	17465-86-0	2.4.1.19, 3.2.1.1, 3.2.1.3
(*R*)-2-decanol	33758-15-5	3.1.1.3
(*R*)-2-decyl butyrate	128942-08-5	3.1.1.3
3-dehydrocarnitine	10457-99-5	1.1.1.108
1,3-diaminopropane	109-76-2	2.6.1.-
dihydro-α-lipoate	462-20-4	1.8.1.4
(*S*)-dihydroorotate	5988-19-2	1.3.99.11
dihydroxonic acid	499-09-2	1.3.99.11
dodecanal	112-54-9	1.14.14.3
1-dodecanoic acid	143-07-7	1.14.14.3, 3.1.1.3
1-dodecanol	112-53-8	3.1.1.3
(*R*)-2-dodecanol	99210-87-4	3.1.1.3
(*R*)-2-dodecyl butyrate	99113-82-3	3.1.1.3
dodecyl dodecanoate	13945-76-1	3.1.1.3
ethanol	64-17-5	3.4.21.1, 1.1.1.1
ethyl-(*E*)-2-octenoate	2351-90-8	2.5.1.18
D-fructose	57-48-7	1.1.1.14, 1.1.1.67, 2.4.1.13, 3.2.1.3, 3.2.1.23, 3.2.1.26, 5.3.1.5
D-fructose 6-phosphate	643-13-0	5.3.1.9
6-*O*-α-**D**-galactopyranosyl-**D**-galactopyranose	13117-25-4	3.2.1.3
D-galactose	59-23-4	3.2.1.3, 3.2.1.23
D-glucono-1,5-lactone	90-80-2	1.1.3.4, 1.11.1.6
4-*O*-α-D-glucopyranosyl-**D**-fructofuranose	17606-72-3	3.2.1.3
3-*O*-α-**D**-glucopyranosyl-lyxopyranose	197901-78-3	3.2.1.3
D-glucose	50-99-7	2.4.1.19, 2.4.1.20, 3.2.1.1, 3.2.1.3, 3.2.1.23, 3.2.1.26, 5.3.1.5
β-**D**-glucose	492-61-5	1.1.3.4, 1.11.1.6
α-**D**-glucose 1-phosphate	59-56-3	2.4.1.20, 2.7.7.9, 2.7.7.-, 5.4.2.2, 5.4.2.8
D-glucose 6-phosphate	56-73-5	5.3.1.9
α-**D**-glucose 6-phosphate	15209-11-7	5.4.2.2, 5.4.2.8
L-glutamate	56-86-0	2.6.1.1, 2.6.1.2, 2.6.1.5, 2.6.1.42, 3.5.1.2
L-glutamate:ammonia ligase (ADP-forming)	9023-70-5	2.7.7.42
L-glutamine	56-85-9	3.5.1.2
glutathione (oxidized)	103239-24-3	1.6.4.2
glutathione (reduced)	70-18-8	1.6.4.2, 2.5.1.18.

5. List of Substances with Chemical Abstract Service (CAS) Registry Numbers with Cross References to Enzyme Commission Numbers—Continued

Substance	CAS Registry Number[a]	Enzyme Commission Numbers
glutathionyl-ethyl-(*E*)-2-octenoate	214403-82-4	2.5.1.18
glutathionyl-methyl-(*E*)-2-octenoate	214403-83-5	2.5.1.18
glutathionyl-(*E*)-3-nonen-2-one	214403-84-6	2.5.1.18
glutathionyl-(*E*)-2-octenal	214403-85-7	2.5.1.18
4-(glutathionyl)-4-phenyl-2-butanone	104786-88-1	2.5.1.18
D-glyceraldehyde 3-phosphate	142-10-9	4.2.1.20
glycerol-1,2-dibutyrate	24814-35-5	3.1.1.3
glycine	56-40-6	1.4.4.2, 2.1.2.1
N-glycolyl-**D**-mannosamine	7483-19-4	4.1.3.3
N-glycolylneuraminate	113-83-3	4.1.3.3
β-guanidinopropionate	353-09-3	2.7.3.2
guanosine 2′:3′-(cyclic)phosphate	15718-49-7	3.1.27.5
guanosine 5′-diphosphate	146-91-8	2.7.4.8
guanosine 3′-methylphosphate	69414-27-3	3.1.27.5
guanosine 3′-monophosphate	6027-83-4	3.1.27.5
guanosine 5′-monophosphate	85-32-5	2.7.4.8
H_2O	7732-18-5	1.1.3.4, 1.1.3.6, 1.3.1.12, 1.7.3.3, 1.11.1.6, 1.11.1.7, 1.14.14.3, 1.14.15.1, 2.1.2.1, 2.4.1.19, 3.1.1.3, 3.1.1.20, 3.1.27.5, 3.2.1.1, 3.2.1.3, 3.2.1.23, 3.2.1.26, 3.4.21.1, 3.4.24.27, 3.5.1.1, 3.5.1.2, 3.5.1.5, 3.5.1.14, 3.5.1.-, 3.5.3.1, 4.2.1.20, 4.2.1.-, 4.-, 5.4.99.6
H_2O_2	7722-84-1	1.1.3.4, 1.1.3.6, 1.11.1.6, 1.11.1.7
(*R*)-2-heptanol	6033-24-5	3.1.1.3
(*R*)-2-heptyl butyrate	117636-45-0	3.1.1.3
hippurate	495-69-2	3.4.21.1
4-hydroxybenzoate	99-96-7	4.1.3.-
(+)-5-*exo*-hydroxycamphor	1607-84-7	1.14.15.1
6-hydroxycyclohex-1-ene-carboxyl-coenzyme A	148471-95-8	4.2.1.-
D-4-hydroxyphenylglycine	22818-40-2	3.5.1.11
4-hydroxyphenylpyruvate	156-39-8	1.3.1.12, 2.6.1.5
L-iditol	488-45-9	1.1.1.14
imidazole	288-32-4	2.7.7.-
indole	120-72-9	4.2.1.20
1-(indol-3-yl)glycerol 3-phosphate	4220-97-7	4.2.1.20
(*R*)-2-(4-isobutylphenyl)propionyl-coenzyme A	105567-78-0	5.1.2.-
(*S*)-2-(4-isobutylphenyl)propionyl-coenzyme A	135027-64-4	5.1.2.-
isochorismate	22642-82-6	5.4.99.6
α-isomaltose	499-40-1	3.2.1.3
β-isomaltose	22352-61-0	3.2.1.3
(*S*)-lactate	79-33-4	1.1.1.27
lactose	63-42-3	3.2.1.23
lactulose	4618-18-2	3.2.1.23
L-leucine	61-90-5	2.6.1.42
α-lipoate	1077-28-7	1.4.4.2, 1.8.1.4
lyxose	1114-34-7	3.2.1.3
D-mannitol	69-65-8	1.1.1.14, 1.1.1.67

5. List of Substances with Chemical Abstract Service (CAS) Registry Numbers with Cross References to Enzyme Commission Numbers—Continued

Substance	CAS Registry Number[a]	Enzyme Commission Numbers
1-*O*-*α*-**D**-mannopyranosyl-**D**-mannofuranose	197902-09-3	3.2.1.3
6-*O*-*α*-**D**-mannopyranose-**D**-mannopyranose	6614-35-3	3.2.1.3
D-mannose	3458-28-4	3.2.1.3, 4.1.3.3
D-mannose 1-phosphate	51306-17-3	5.4.2.8
D-mannose-6-phosphate	70442-25-0	5.4.2.8
α-**D**-melibiose	585-99-9	3.2.1.3
β-D-melibiose	29873-67-4	3.2.1.3
(−)-menthol	2216-51-5	3.1.1.3
(−)-menthyl dodecanoate	57084-14-7	3.1.1.3
methanol	67-56-1	3.1.27.5
L-methionine	63-68-3	3.5.1.14
5,10-methylenetetrahydrofolate	3432-99-3	2.1.2.1
methyl-(*E*)-octenoate	2396-85-2	2.5.1.18
4-methyl-2-oxopentanooate	816-66-0	2.6.1.42
β-nicotinamide-adenine dinucleotide (oxidized)	53-84-9	1.1.1.1, 1.1.1.27, 1.1.1.56, 1.1.1.108, 1.1.1.141, 1.3.1.12, 1.6.4.2, 1.8.1.4, 1.14.15.1
β-nicotinamide-adenine dinucleotide (reduced)	606-68-8	1.1.1.1, 1.1.1.27, 1.1.1.56, 1.1.1.108, 1.1.1.141, 1.3.1.12, 1.6.4.2, 1.8.1.4, 1.14.15.1
β-nicotinamide-adenine dinucleotide phosphate (oxidized)	53-59-8	1.1.1.67, 1.6.4.2
β-nicotinamide-adenine dinucleotide phosphate (reduced)	2646-71-1	1.1.1.67, 1.6.4.2
(*R*)-2-nonanol	628-99-9	3.1.1.3
(*E*)-3-none-2-one	14309-57-0	2.5.1.18
(*R*)-2-nonyl butyrate	117636-46-1	3.1.1.3
O_2	7782-44-7	1.1.3.4, 1.1.3.6, 1.7.3.3, 1.11.1.6, 1.14.14.1, 1.14.15.3
(*E*)-2-octenal	2548-87-0	2.5.1.18
(*R*)-2-octanol	5978-70-1	3.1.1.3
(*R*)-2-octyl butyrate	89378-60-9	3.1.1.3
L-ornithine	70-26-8	3.5.3.1
orotate	65-86-1	1.3.99.11
orthophosphate	10049-21-5	2.4.1.20, 2.5.1.7
oxaloacetate	328-42-7	2.6.1.1
2-oxo-3-deoxy-**D**-glycero-**D**-galacto-nonopyranulosonate	124233-95-0	4.1.3.3
2-oxoglutarate	328-50-7	2.6.1.1, 2.6.1.2, 2.6.1.5, 2.6.1.42
oxonic acid	2207-75-2	1.3.99.11
15-oxo-prostaglandin E_2	26441-05-4	1.1.1.141
L-phenylalanine	63-91-2	2.6.1.5
L-phenylalanine methyl ester	2577-90-4	3.4.24.27
(*E*)-4-phenyl-3-buten-2-one	1896-62-4	2.5.1.18
phenylpyruvate	156-06-9	2.6.1.5, 4.2.1.51
N^{ω}-phospho-**L**-arginine	108321-86-4	2.7.3.3
(*Z*)-phospho*enol*butyrate	31302-64-4	2.5.1.7
O-phosphocholine	107-73-3	2.7.1.32
phosphocreatine	6190-45-0	2.7.3.2
phosphocyclocreatine	61839-19-8	2.7.3.2
3-phospho-**D**-glycerate	820-11-1	2.7.2.3

5. List of Substances with Chemical Abstract Service (CAS) Registry Numbers with Cross References to Enzyme Commission Numbers—Continued

Substance	CAS Registry Number[a]	Enzyme Commission Numbers
3-phospho-**D**-glyceroyl phosphate	38168-82-0	2.7.2.3
β-phosphoguanidinopropionate	55601-59-7	2.7.3.2
N^{ω}-phosphotaurocyamine	4189-99-5	2.7.3.4
prephenate	126-49-8	1.3.1.12, 4.2.1.51, 5.4.99.5
1-propanol	71-23-8	3.1.1.20
2-propanol	67-63-0	3.4.21.1
2-propylhippurate	1776-56-3	3.4.21.1
prostaglandin E_2	363-24-6	1.1.141
pyrophosphate	2466-09-3	2.7.7.9, 2.7.7.42
pyruvate	127-17-3	1.1.1.27, 2.6.1.2, 2.6.1.-, 4.1.3.3, 4.1.3.-, 4.2.1.20
ribitol	488-81-3	1.1.1.56
riboflavin 5′-phosphate (oxidized)	146-17-8	1.14.14.3
riboflavin 5′-phosphate (reduced)	5666-16-0	1.14.14.3
D-ribulose	488-84-6	1.1.1.14, 1.1.1.56
L-serine	56-45-1	2.1.2.1, 2.3.1.30, 4.2.1.20
D-sorbitol	50-70-4	1.1.1.14
L-sorbose	87-79-6	1.1.1.14
sucrose	57-50-1	2.4.1.13, 3.2.1.26
taurocyamine	543-18-0	2.7.3.4
tetraglutamyl-5,10-methylenetetrahydrofolate	60283-91-2	2.1.2.1
tetraglutamyl-5,6,7,8-tetrahydrofolate	50998-24-8	2.1.2.1
5,6,7,8-tetrahydrofolate	135-16-0	2.1.2.1
thiocyanate (oxidized)	63296-34-4	1.11.1.7
thiocyanate (reduced)	463-56-9	1.11.1.7
tributyrylglycerol	60-01-5	3.1.1.3
3,4,5-trihydroxybenzoate	149-91-7	3.1.1.20
3,4,5-trihydroxybenzoic acid propyl ester	121-79-9	3.1.1.20
L-trytophan	73-22-3	4.2.1.20
L-tyrosine	60-18-4	2.6.1.5
(*R*)-2-undecanol	85617-06-7	3.1.1.3
(*R*)-2-undecyl butyrate	181148-07-2	3.1.1.3
urate	69-93-2	1.7.3.3, 1.11.1.6
urea	57-13-6	3.5.1.5, 3.5.3.1
uridine 2′:3′-(cyclic)phosphate	15718-50-0	3.1.27.5
uridine 5′-diphosphate	58-98-0	2.4.1.13
uridine 5′-diphospho-*N*-acetyl-**D**-glucosamine	91183-98-1	2.5.1.7
uridine 5′-diphosphogalactose	89705-69-1	5.1.3.2
uridine 5′-diphosphoglucose	133-89-1	2.4.1.13, 2.7.7.9, 2.7.7.-, 5.1.3.2
uridine 5′-phosphoimidazole	214403-86-8	2.7.7.-
uridine 3′-monophosphate	35170-03-7	3.1.27.5
uridine 5′-triphosphate	63-39-8	2.7.7.9
xylitol	87-99-0	1.1.1.14
D-xylulose	551-84-8	1.1.1.14

[a]In some cases the CAS registry number refers to a salt of the substance.

6. Abbreviations

ADP	adenosine 5′-diphosphate	Mops	3-morpholinopropanesulfonic acid
AMP	adenosine 5′-monophosphate	NAD	β-nicotinamide-adenine dinucleotide (oxidized)
ATP	adenosine 5′-triphosphate	NADH	β-nicotinamide-adenine dinucleotide (reduced)
Bicine	*N*,*N*-bis(2-hydroxyethyl)glycine	NADP	β-nicotinamide-adenine dinucleotide phosphate (oxidized)
Ches	2-(cyclohexylamino)ethanesulfonic acid	NADPH	β-nicotinamide-adenine dinucleotide phosphate (reduced)
CoA	coenzyme A	Pipes	piperazine-*N*,*N*′-bis(2-ethanesulfonic acid)
GDP	guanosine 5′-diphosphate	Tes	*N*-tris(hydroxymethyl)methyl-2-aminoethane-sulfonic acid
Hepes	*N*-(2-hydroxyethyl)piperazine-*N*′-ethanesulfonic acid	Tris	tris(hydroxymethyl)aminomethane
Mes	2-(*N*-morpholino)ethanesulfonic acid	UDP	uridine 5′-diphosphate

7. Glossary of Symbols

Symbol	Name	Unit
c	concentration	$\mathrm{mol\,dm^{-3}}$
c°	standard concentration ($c^\circ = 1\,\mathrm{mol\,dm^{-3}}$)	$\mathrm{mol\,dm^{-3}}$
$\Delta_r C_p^\circ$	standard heat capacity of reaction at constant pressure	$\mathrm{J\,K^{-1}\,mol^{-1}}$
$\Delta_r G^\circ$	standard Gibbs energy of reaction	$\mathrm{kJ\,mol^{-1}}$
$\Delta_r G'^\circ$	standard transformed Gibbs energy of reaction	$\mathrm{kJ\,mol^{-1}}$
$\Delta_r H^\circ$	standard enthalpy of reaction	$\mathrm{kJ\,mol^{-1}}$
$\Delta_r H'^\circ$	standard transformed enthalpy of reaction	$\mathrm{kJ\,mol^{-1}}$
$\Delta_r H(\mathrm{cal})$	calorimetrically determined enthalpy of reaction	$\mathrm{kJ\,mol^{-1}}$
I_c	ionic strength, concentration basis	$\mathrm{mol\,dm^{-3}}$
I_m	ionic strength, molality basis	$\mathrm{mol\,kg^{-1}}$
K	equilibrium constant[a]	dimensionless
K'	apparent equilibrium constant[a]	dimensionless
m	molality	$\mathrm{mol\,kg^{-1}}$
m°	standard molality ($m^\circ = 1\,\mathrm{mol\,kg^{-1}}$)	$\mathrm{mol\,kg^{-1}}$
$\Delta_r N(\mathrm{H^+})$	change in binding of hydrogen ion in a biochemical reaction	dimensionless
P	pressure	Pa
pH	$-\log_{10}\{c(\mathrm{H^+})/c^\circ\}$[b]	dimensionless
pX	$-\log_{10}\{c(X)/c^\circ\}$	dimensionless
$\Delta_r S^\circ$	standard entropy of reaction	$\mathrm{J\,K^{-1}\,mol^{-1}}$
T	thermodynamic temperature	K
x	mole fraction	dimensionless

[a]When needed, a subscript c, m, or x is added to these quantities to designate a concentration, molality, or mole fraction basis.

[b]This is an approximate definition. The IUPAC Green Book [I. Mills, T. Cvitaš, K. Homann, N. Kallay, and K. Kuchitsu, *Quantities, Units and Symbols in Physical Chemistry* (Blackwell Scientific, Oxford, 1993)] contains a discussion of the operational definition of pH.

8. Reference Codes and References in the Table

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